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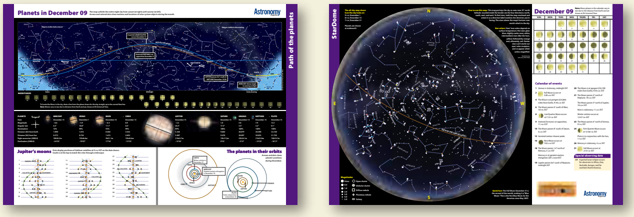

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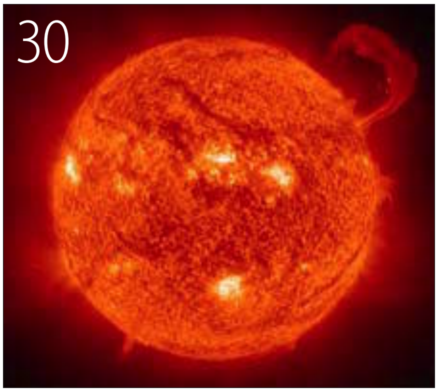

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Astronomy (ISSN 0091-6358, USPS 531-350) is published monthly by Kalmbach Publishing Co., 21027 Crossroads Circle, P. O. Box 1612, Waukesha, WI 53187–1612. Periodicals postage paid at Waukesha, WI, and additional offices. POSTMASTER: Send address changes to *Astronomy*, 21027 Crossroads Circle, P. O. Box 1612, Waukesha, WI 53187–1612. Canada Publication Mail Agreement # 40010760.

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Introducing *Astronomy* Magazine Observatory

by David J. Eicher

When I first came to *Astronomy* magazine in the fall of 1982, I had many discussions with then-Editor Richard Berry and Associate Editor Robert Burnham. We used to envision the day when the magazine would have a dark-sky observatory facility to use as a test bed for telescopes, imaging setups, and observing that could benefit many stories throughout the publication. Setting up such a thing in a dark sky was complicated, however, and although the subject came up among the editors every few years, we never got the thing going. The daily responsibilities of putting out the magazine always pushed such a vision off.

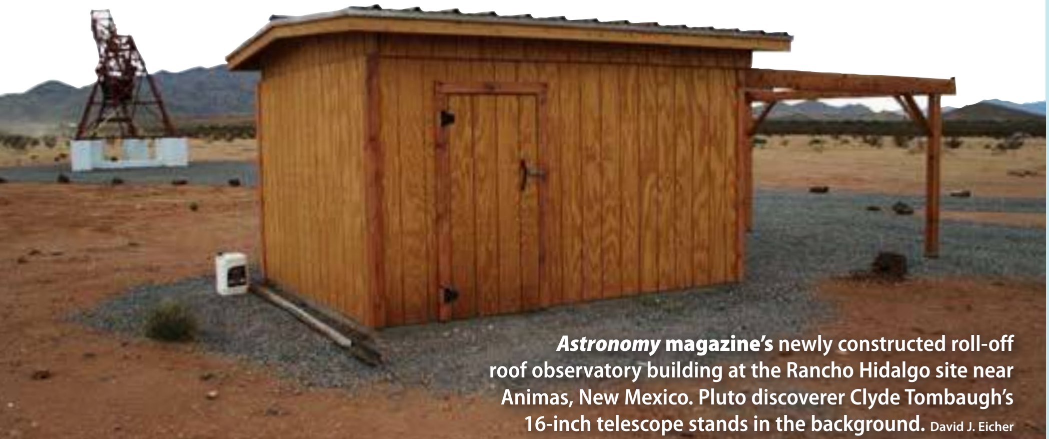
Now, however, I am proud to announce the creation of the *Astronomy* Magazine Observatory. (The first lesson: Keep trying with good ideas. This one took 27 years until it succeeded!) In partnership with Gene Turner, owner of Rancho Hidalgo Astronomy Village and Arizona Sky Village, our magazine has established an observatory facility — under some of the darkest skies I've ever seen — outside the small town of Animas, New Mexico, at Rancho Hidalgo. The primary instrument will be a 14-inch SCT, and we will also have a CCD imaging setup and Hydrogen-alpha (Hα) solar telescope.

In the coming months and years, we'll use the *Astronomy* Magazine Observatory for a variety of applications. They include dark-sky observing we'll feature in stories and shooting images of deep-sky objects to feature in the magazine and on the web site. We'll also provide Hα images of the Sun on our home page so you can track our local star's activity. Additionally, we'll use the location as a testing facility for equipment reviews you'll see in the magazine.

I want to thank Gene Turner for his unceasing support of astronomy education in this and other ventures, and I encourage you to check out his web site, www.hidalgonm.com, to see what's cooking at Rancho Hidalgo. I also want to thank Publisher Kevin Keefe, President Butch Boettcher, and Executive Vice President Chuck Croft for supporting the idea. It will pay off in many ways that you will see over and over again in the pages of the magazine and on our web site.

Yours truly,

David J. Eicher
Editor



***Astronomy* magazine's** newly constructed roll-off roof observatory building at the Rancho Hidalgo site near Animas, New Mexico. Pluto discoverer Clyde Tombaugh's 16-inch telescope stands in the background. David J. Eicher

Astronomy

Volume 37, Number 12

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Astroconfidential

by Karri Ferron

Go beyond the latest discovery, research, or theory and meet the professionals who make it all possible.

A+ To learn more about the people featured this month, visit www.Astronomy.com/toc.

GETTING TO KNOW

Seth Shostak

Jill Tarter

Bernard M. Oliver Chair for SETI Research and director of the Center for SETI Research at the SETI Institute in Mountain View, California

Coolest thing you've done in your career: I've used some of the world's best scientific instruments, and I've partnered with the University of California at Berkeley to build a better radio telescope than has ever been built — the Allen Telescope Array (ATA). It will fundamentally change the way radio telescopes are built in the future. It is a pathfinder for the International Square Kilometer Array. It's fabulous to have had that kind of influence, to invent a new way of looking at the sky that will allow us to do not only SETI but new kinds of radio astronomy that haven't been possible in the past.

Best way to get more people excited about astronomy: We must present astronomy as an extraordinarily accessible scientific discipline that is all about answering questions we don't yet have answers to. We don't do a very good job of portraying an astronomer's life as one that is incredibly fun, different, and satisfying. I always like to tell kids, "If you decide to be a scientist, you don't ever have to grow up. You can stay a kid asking the 'why' question forever and have the amazing satisfaction of finding an answer to even one little 'why' that no one else has found. You can be an explorer, and you can make a difference."

Goals: By the time I retire, I want to have found a vehicle of continuing funding for SETI, something that could go on for centuries. I realize that the search we are contemplating and starting is vast and enormous and may take a long time to have an expectation of success.

Setting up an endowment is the only vehicle I've have been able to come up with that has that capability of long-term funding. Perhaps against all expectations, we might succeed and answer the question of extraterrestrial life in my lifetime, which would be terrific. But I won't feel disappointed or unhappy if we don't as long as I can set up the structure so the search can continue.

Astroideas

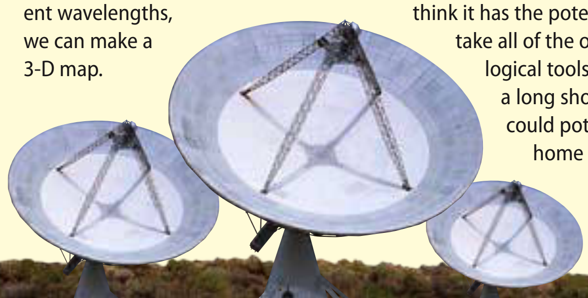
What's making waves in cosmology?

I am excited about a new cosmological tool called 21-centimeter tomography, or neutral-hydrogen tomography. The basic idea is to map our universe in 3-D. Despite all the breakthroughs we've had in cosmology, we've mapped only a tiny fraction of our observable universe.

The basics of neutral-hydrogen tomography are simple. All space is full of hydrogen gas. And neutral hydrogen gas gives off radio waves that we can measure with radio telescopes. These radio waves are 21 centimeters if they're nearby, but longer if they're far away because the expansion of the universe has stretched them. By looking in all different directions at all of these different wavelengths, we can make a 3-D map.

So it's easy in principal, but no one has been able to do it so far because the signals are very faint and require really big telescopes, which are expensive … we thought. I've been working on a new idea for building these kinds of telescopes on the cheap using off-the-shelf electronics that the members of the computer industry have given to us — using some clever analysis tricks where a telescope ended up costing way less than we used to think.

I'm psyched about this technique because if we can get it all to work, I think it has the potential to overtake all of the other cosmological tools we have. It's a long shot, but it could potentially be a home run.



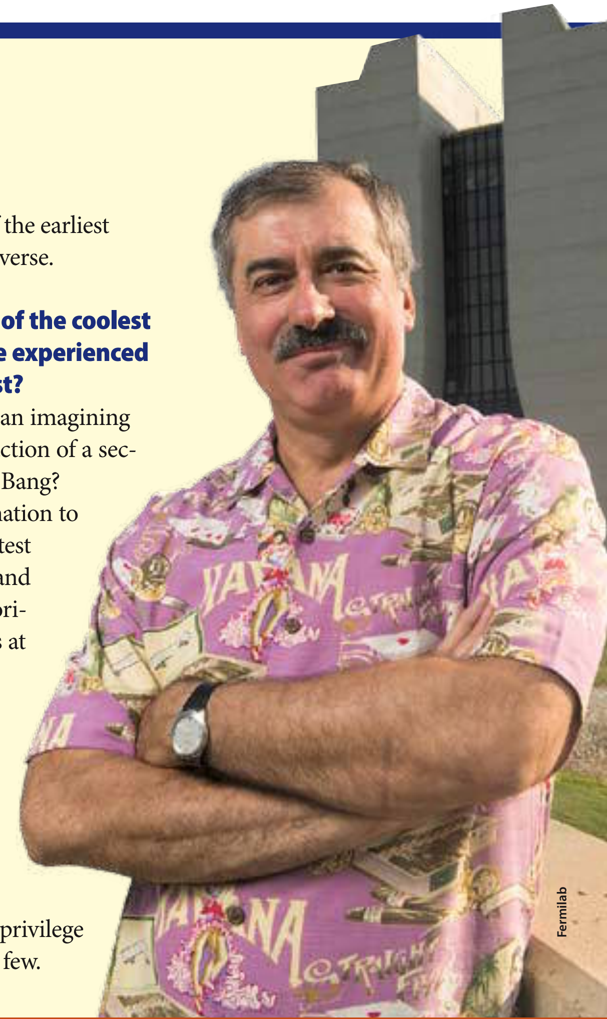
Max Tegmark

Professor of physics at the Massachusetts Institute of Technology

Courtesy Max Tegmark

Rocky **Kolb**

Professor and chair of the University of Chicago's Department of Astronomy and Astrophysics



Fermilab

What single question about our universe would you like to have answered?

One of the nice things about cosmology is that the questions we try to answer are simple to state, although sometimes the answers are a bit complicated. I would like to know what the universe is made of.

Cosmologists today think about 95 percent of the stuff in the universe is dark: 23 percent dark matter holding together individual galaxies and other cosmic structures and 72 percent dark energy driving the structures apart from one another in an accelerated cosmic expansion. Dark matter and dark energy are just names for things we don't understand. Ninety-five percent of the universe is a mystery! I would like to solve the mysteries of dark energy and dark matter. I would even settle for solving one.

What's going to blow the lid off the study of cosmology?

Sometime before the end of 2009, we should see the first collisions in the Large Hadron Collider (LHC) particle accelerator at CERN in Geneva, Switzerland. In the collisions at accelerators like CERN or Fermilab outside Chicago, we re-create and study conditions of energy, temperature, and pressure that have not existed since the earliest moments of the Big Bang.

We don't know what we will discover, but we will search for dark-matter particles, new symmetries in the laws of nature, the Higgs boson, and extra spatial dimensions. Unexpected discoveries could revolutionize our understanding of the earliest history of the universe.

What are some of the coolest things you have experienced as a cosmologist?

What is cooler than imagining the universe a fraction of a second after the Big Bang? Using our imagination to explore the remotest reaches of space and time, even their origins or their ends at black holes, is a remarkable experience. To be part of this journey, the collective scientific enterprise to understand the universe, is a privilege granted only to a few.

Astro**influences**

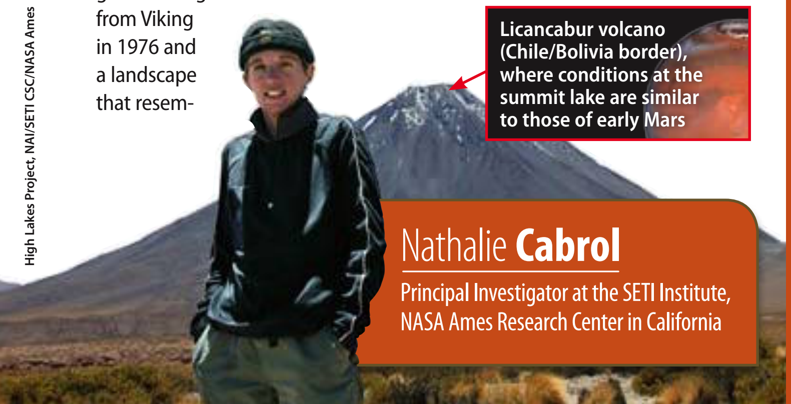
How did you become interested in studying Mars?

I actually think I've always been interested in studying Mars and space. I was born knowing this is what I wanted to do!

I was 5 when Neil Armstrong walked on the Moon. Living with my family in France, it was the middle of the night when the Eagle landed. My mom and I were tucked against each other on the living-room couch looking at the ghostly black-and-white images of Armstrong climbing down the ladder and setting foot on the Moon. My mom has said I told her I wanted to explore space that night.

Mars came later, with the first ground images from Viking in 1976 and a landscape that resembled our home planet. My parents were supportive and bought me books and all they could find to feed my passion for space exploration.

Today, I study Mars by visiting the high lakes of places like Licancabur volcano in the Andes. These areas have cold, dry climates and an abundance of ultraviolet radiation – all characteristic of conditions on Mars. There, my team tries to understand the evolution of ancient martian lakes and their potential for life.



Licancabur volcano (Chile/Bolivia border), where conditions at the summit lake are similar to those of early Mars

High Lakes Project, NAI/SETI CSC/NASA Ames

Nathalie **Cabrol**

Principal Investigator at the SETI Institute, NASA Ames Research Center in California

Astro**fascinations**

What fascinates you most about the growth of cosmic structure?

I first became intrigued with the growth of cosmic structure during a cosmology course in college. The process is simply amazing. Pictures of galaxies and star-formation regions in the nearby universe show an incredibly intricate and complex network of structures. All of these structures emerged from a medium that was everywhere uniform to an astonishing level — better than 1 part in 100,000. It's like the city of Atlantis emerging from Lake Placid!

And even more amazing is that much of the growth of this complex and varied structure is governed by a relatively small handful of simple physical principles. That such complexity is understandable and that the underlying rules and regulations of the universe are knowable is intoxicating.

James Buckwalter

Juna **Kollmeier**

Astronomer with the Carnegie Observatories in Pasadena, California

Letters

Making our way back to the Moon

I wanted to send along my praise and appreciation for the contents of the August 2009 issue. James Oberg's lead article, "How we'll return to the Moon," changed my thinking. For a long time, I have bemoaned the time we've "wasted" in not getting our space exploration act together far earlier than this. But maybe advances in technology — like better spacecraft and better space suits — and conceptual breakthroughs like abort-to-surface contingency plans will mean that we'll do a better, safer job of it in 2020 than we would have at any time before.

According to the "Mars now!" people, we're way behind, but Oberg's article helps clarify how much there was to learn to get here. We haven't lost or wasted anything; humanity is still on its slow, sure way to the stars. — **George Stacey,** Calgary, Alberta

NASA

The Apollo 17 mission in December 1972 marked NASA's last manned Moon mission.

Why not robots?

Thanks for the informative articles in the August 2009 issue on returning to the Moon and then "Next stop Mars?" One can sense the adventure there.

But neither article answered the question: Why send humans to either place, when robots are effective, much less expensive, and a lot safer?

I worry that billions of dollars spent on human exploration will seriously reduce funding for further robotic missions to Mars, along with other exciting places like Europa, Titan, Enceladus, and Triton. Even more tragic would be the loss of life on such human missions.

We can still have adventure through the robots, just like we've been having with the Mars rovers, the twin Voyager spacecraft, and many others. — **Earl Finkler,** Medford, Wisconsin

No stepping on Mars

I was 20 when we landed on the Moon, and I still vividly remember the tension and exhilaration from that moment. I can't imagine what it would be like to witness mankind touching down on Mars.

Having said that, I really don't understand why we're trying to send humans to Mars, other than to perhaps satisfy some highly charged, testosterone-driven urge. I understand the public-relations benefit of humans versus robots and appreciate the recruiting benefits to bring new scientists to the forefront. But it's fraught with personal risks and sucks up huge amounts of money and brainpower that could be better used.

In lieu of manned missions, we could fund many more unmanned missions to Mars as well as many other intriguing solar system bodies (particularly moons). Further, in that same time frame, advances in robotics and artificial intelligence would resolve most of the issues of "discoveries that only man could make" without risking the lives of human beings.

I know it's "Robo" and not "Neil," but robotic missions are safer, less expensive, and could achieve far more in less time. — **Frank Hanou,** Indianapolis

Galactic gratitude

I enjoyed looking through *Astronomy* magazine's special issue *The Milky Way Inside and Out*. What a marvelous work. The inclusion of my image of Omega Centauri (NGC 5139) means a lot; thank you. I hope everyone who gets the chance to read *The Milky Way Inside and Out* will realize and appreciate how much energy goes into producing something that comprehensive. Well done! — **Daniel B. Phillips,** Oceanside, California

Moonbow madness

Stephen James O'Meara's August 2009 column, "Moonbows: architecture of light" was fascinating. It gives me something new to look for! One of the natural thrills of my life was watching a moonbow at Victoria Falls in Zambia one night. The Moon was full and the moonbow quite bright in the mist of the falls. — **Keith Gunnar,** Langley, Washington

Publication praise

I am a 60-year-old Catholic priest who has been an amateur astronomer since I got my first telescope at age 10. I want to let you know how much I appreciate *Astronomy* magazine. Every month, I go first to Bob Berman's "Strange Universe." Then I read the rest of the publication from cover to cover.

As a person of faith, I am convinced that the search for knowledge in all its forms is a holy enterprise. Thanks for all that you do to promote astronomy. — **Patrick J. Madden,** Shreveport, Louisiana

Astro Confidential's astrophysics

I think *Astronomy* improves with each issue. August 2009 was especially thrilling as you continued to publish more scientists' explanations of their research and achievements ("Astro Confidential"). You are moving deeper into the astrophysics issues that are leading-edge. Hoorah! — **Claire Schmidt,** Zionsville, Indiana

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We welcome your comments. Send letters to Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

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Sketching NGC 1023
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Strange Universe

by Bob Berman

Milky Way mysteries

After centuries of observations, studies of our galaxy still reveal bizarre features.

Through countless centuries, a frustrating mystery sprawled across the sky: What was that strange glowing band? Mesoamericans pictured it as the path to heaven taken by the dead. Medieval Europeans called it *Via Galactica*, the "milk road." After Galileo aimed his little refractor at it in December 1609, he wrote, "All the disputes which have vexed philosophers through so many ages have been resolved, and we are at last freed from wordy debates about it. The [Milky Way] is, in fact, nothing but … innumerable stars."

But wordy debates didn't end. They were only beginning.

The easy part was realizing we're embedded in a flat pancake of countless stars. But what about those smudgy spirals that pepper the heavens everywhere *except* within the Via Galactica? Could they lie *beyond* the Milky Way? Could our city of suns be just one of many?

Even by the early 20th century, no one knew the answer. Enter Missourian Edwin Hubble. After studying in Chicago, he attended Oxford University, where he acquired a British accent that he never shed, to the annoyance of everyone. Arrogant and unpleasant, Hubble got his hands on the new 100-inch Hooker telescope at the Mount Wilson Observatory in California and thus became the first to learn the truth, and, well, you can't take that away from him.

Those structures are colossal and achingly distant. But what to call them? Philosopher Immanuel Kant coined the lovely term "Island Universes" that competed for a while with "spiral nebulae." But soon they were simply called galaxies. "Galactic" means "like-milk," so we essentially pictured the cosmos as a vast dairyland.

Browse the "Strange Universe" archive at www.Astronomy.com/Berman.

Pinpointing the center of our own galaxy was easy. All 150 globular clusters surround one spot, like lights on a globe chandelier. It coincides with the brightest part of the Milky Way in Sagittarius.

Figuring out our spin came next. Because a supermassive black hole sits heavily in the center, you'd think stars orbiting closer to the inner sections would whiz superfast. After all, Mercury travels some 10 times faster than poor demoted Pluto. Strangely enough, this doesn't necessarily happen. Some inner parts of our galaxy rotate at 120 miles per second (200 kilometers per second) while our Sun orbits faster, not slower, at 140 miles per second (220 km/s). In regions even farther out, toward Orion, star speeds pretty much match our own. The galaxy spins almost like a solid vinyl record.

We essentially pictured the cosmos as a vast dairyland.

This can happen only if there's 8 times more gravity in our galaxy than all the stars, dust, and anything else we could account for. We don't know what this stuff is; we call it dark matter. So our familiar spiral is like a ship in a bottle, embedded within copious amounts of unseen material that doesn't even *reflect* light.

Some blamed dark matter for the strange energy flashes observed throughout our galaxy. But this past summer, new data showed that the culprit is antimatter. Exploding stars create positrons, the antimatter version of electrons. When those two meet, far from the original supernova, they explode into a hail of gamma rays. Our galaxy is full of odd tricks.

Our sidekick Andromeda spins at about the same speed we do, with its northern half rotating toward us. It's heading our way at some 75 miles per second (120 km/s), but don't hold your breath waiting for the collision. The sluggish closing speed is not for impatient types. Place two footballs on opposite sides of a 25-foot living room; that's the true scale. Andromeda's football moves its own length every 300 million years. It's probably approaching at an angle, so it will miss us, and then return. It could be 5 billion years before we finally merge. By then our Sun will be a red giant, and your home's value will be in the cellar.

Andromedans see us as a nearly edgewise galaxy. They can't really view our spiral arms. Too bad for them. Spirals — winding out from the center for up to 1½ full turns — are where the action is. Interestingly, spiral arms rotate more slowly than the rest of the galaxy. Orbiting stars and nebulae catch up to the arms and temporarily slow down, thanks to the extra gravity there. This maintains the spirals as realms of higher density, where dazzling blue suns hatch within the red campfires of dusty nebulae. Backyard scopes easily see this grandeur unfolding in our neighborhood's arms of Orion and Sagittarius.

Galaxies always rotate in the direction that should make the spirals wind up tighter over time. Yet they do not change; the arms stay the same. Weird. And forever fascinating.

It's a shame Galileo — who uncovered the Milky Way's reality exactly 400 years ago — never had a telescope good enough to see the spirals of a single galaxy.

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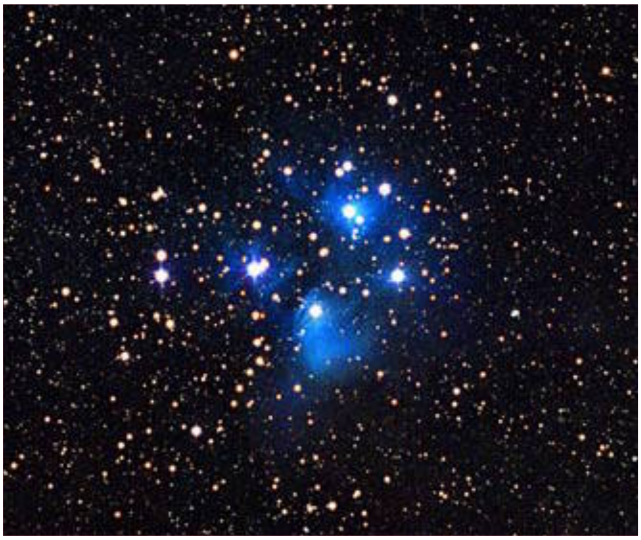
Observing Basics

by Glenn Chaple

Study the Seven Sisters

The Pleiades is one of the nearest star clusters to Earth and a popular observing target.

Four centuries ago, the Italian astronomer Galileo Galilei opened up the universe with his telescope. Among his discoveries were mountains and craters on the Moon, four bright satellites orbiting Jupiter, and the changing phases of Venus — all of which contradicted the common belief of a perfect Earth-centered universe.



The Pleiades star cluster (M45) has caught the attention of skygazers since ancient times. Under normal conditions, most observers can see six Pleiads without optical aid. Chris Schur

Galileo's telescope also revealed myriad stars invisible to the unaided eye. In his 1610 *Sidereus Nuncius* ("Starry Messenger"), Galileo described the previously unseen stars accompanying Orion's Belt and the Pleiades star cluster. Of the latter, he wrote, "Near them are more than forty others, invisible, not one of which is much more than half a degree away from the original six."

Galileo didn't discover the Pleiades. People have known and revered this eye-catching clutch of stars in Taurus since ancient times. Indeed, virtually every early civilization mentions them in writings and lore. More recently, the 19th-century English poet Alfred Tennyson aptly described the Pleiades when he wrote: "Many a night I saw the Pleiades, rising thro' the mellow shade, / Glitter like a swarm of fireflies tangled in a silver braid."

Under normal conditions, most observers can see six Pleiads with the unaided eye. This begs the question: Why are the Pleiades commonly known as the Seven Sisters? Some astronomers surmise that a seventh star, visible in ancient times, has since faded from view. The half-dozen we can see form the outline of a tiny dipper, leading the uninitiated to mistake it for the Little Dipper. Keen-eyed observers may glimpse the seventh Sister, plus about a half-dozen more. Our own Stephen James O'Meara has tallied 17. Although he accomplished this feat from an area just outside Boston, naked-eye Pleiades star counts are best done from a rural setting on a clear moonless night. How many can you make out?

As beautiful as the Pleiades may be to the unaided eye, they come alive in binoculars. At public star parties, I use the Pleiades to dispel the myth that observing with a large, high-power telescope is the only way to enjoy the wonders of the night sky. After showing guests the Pleiades with a 10-inch reflector at 250x, I invite them to look through ordinary 7x50 binoculars. The difference is dramatic. The big scope with its limited field can capture only a few Pleiads, while the entire cluster plus a few dozen other members sparkle in the binocular field.

Some telescopes offer jaw-dropping views of the Pleiades. The "dipper" spans about 1°, while outlying stars double that dimension. You can accommodate this area using a low-power "rich-field" telescope (RFT). Such an instrument gives you the chance to view the gaseous wreaths that envelop the Pleiades. Vividly portrayed in astrophotos, the nebulosity reportedly has been detected with the unaided eye and binoculars. I've seen the brightest part, which surrounds the star Merope, with a 6-inch RFT. Be forewarned. If all of the Pleiades stars appear fuzzy, it's likely a result of dew fogging your telescope's objective.

Don't let the delicate appearance of the Pleiades fool you. The brightest member, Alcyone, is 1,000 times more luminous than our Sun. Put in the Sun's place, it would instantly incinerate all life on Earth. Here's another thought to ponder. Most sources place the Pleiades at a distance of about 400 light-years. Thus, the light you see left this cluster of stars around the time Galileo was mapping them with his telescope.

This column concludes our yearlong celebration of Galileo's discoveries. If you're a novice, I hope you enjoyed the same excitement of discovery Galileo did 4 centuries ago. I also trust that you veteran backyard astronomers availed yourselves of an opportunity to rediscover the marvels that hooked you on astronomy. The International Year of Astronomy has come to a close, but the celebration isn't over. As Senior Editor Michael Bakich notes, "At *Astronomy* magazine, every year is the Year of Astronomy!"

Questions, comments, or suggestions? E-mail me at gchaple@hotmail.com. Next month: The dangers of screw-in solar filters. Clear skies!

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and much more!

Asteroid moons On August 16, astronomers discovered two moons orbiting the asteroid 93 Minerva. One is 2.5 miles (4 km) in diameter, and the other 1.9 miles (3 km).

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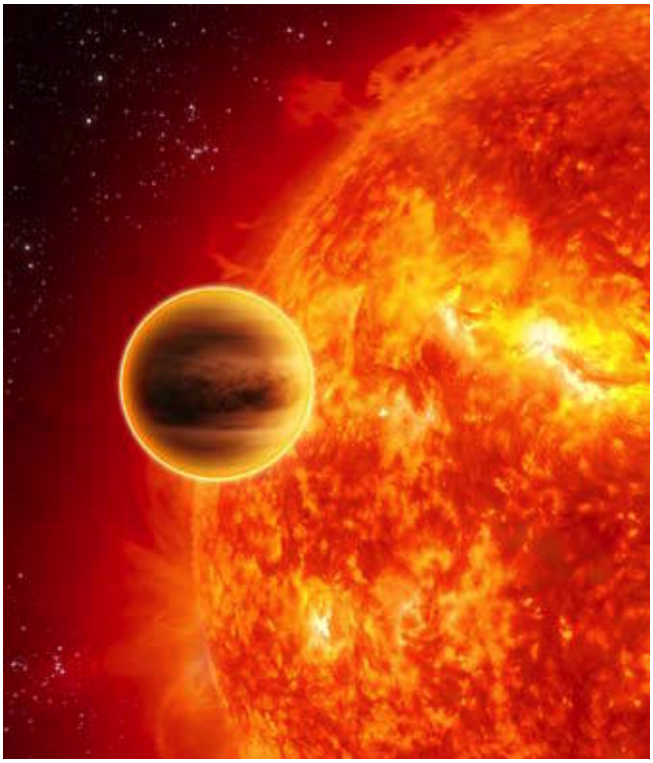


Hot planet. Astronomers discovered the gas giant exoplanet WASP-17b as it transited its host star in a system that resembles this artist's illustration. The unusual new planet orbits in a direction opposite its host star's spin. ESA/C. Carreau

New planet orbits on wrong-way path

Astronomers have discovered hundreds of exoplanets in the past 15 years. But they've never found one like WASP-17b. This planet orbits its host star in a direction opposite that of the star's spin.

The object orbits a 12th-magnitude star that lies some 1,000 light-years from Earth. This star is one of hundreds of thousands monitored by the Wide Angle Search for Planets (WASP). The search, run by a group of United Kingdom universities, looks for periodic dips in a star's brightness that reveal a transiting exoplanet.

All other planets with known orbits revolve around their parent stars in the same direction their stars spin. This makes sense because planets form out of the same swirling disk as their host stars.

What happened to WASP-17b? Astronomers think it may have passed close to a sibling planet. "A near collision during the early, violent stage of this planetary system could well have caused a gravitational slingshot, flinging WASP-17b into its backwards orbit," says David Anderson of Keele University in Staffordshire county, England. Anderson and his colleagues announced their findings August 12 in a paper submitted to *The Astrophysical Journal.*

WASP-17b also has the lowest density of any known planet. It weighs half of what Jupiter does but has a diameter twice as big. This gives it a density less than 15 percent of Jupiter's. — **RICHARD TALCOTT**

20 Gamma rays detected in globular cluster

20 WISE up in orbit

21 This planet should not exist

22 Storms pop up on Titan

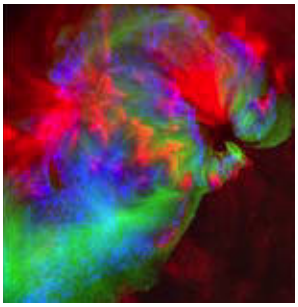
23 Comet harbors life's building block

Why the Sun's corona is "so darned hot"

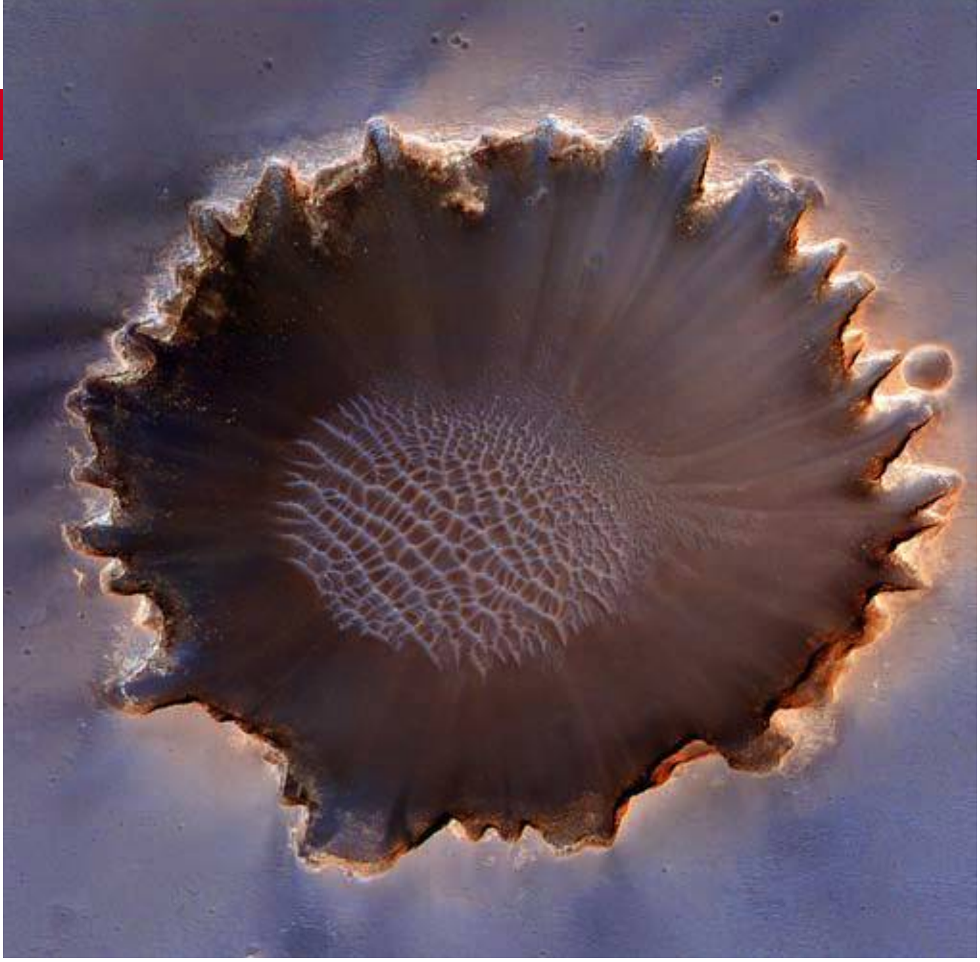
For decades, scientists have puzzled over why the Sun's corona radiates at several million degrees while its surface puts out 9900° F (5500° C). New observations, combined with a new model, point to "nanoflares" as the culprit. These are small, sudden bursts of energy within the Sun's outer atmosphere, or corona. James Klimchuk of NASA's Goddard Space Flight Center presented the result August 6 at the IAU General Assembly meeting in Rio de Janeiro, Brazil.

The Sun's corona is made up of loops of hot gas that arch above the solar surface. Bundles of smaller magnetic tubes make up the loops. Nanoflares are the bursts of energy occurring within the magnetic tubes.

Klimchuk and colleagues created a model to show what happens when nanoflares erupt. They then compared the model with observations from instruments aboard Japan's Hinode satellite. The instruments measured superhot plasma, "which can only be produced by the impulsive energy bursts of nanoflares," says Klimchuk. — **LIZ KRUESI**



Hot matter. In this false-color temperature map of an active region on the Sun's disk, blue regions indicate material at temperatures near 18 million degrees Fahrenheit (10 million degrees Celsius). Reale, et al. (2009)



Scalloped crater. The Mars Reconnaissance Orbiter snapped this picture of Victoria Crater in July. Look for tracks from the Opportunity rover to the left of the crater's rim. NASA/JPL-Caltech/ University of Arizona

Bull's-eye on the Red Planet

The Mars Reconnaissance Orbiter (MRO) spacecraft has been circling the Red Planet for more than 3 years, but it has yet to find many sites as beautiful as Victoria Crater.

MRO's High Resolution Imaging Science Experiment photographed this crater in October 2006 while the Opportunity rover was exploring it. MRO returned to the scene July 18.

The new image, released August 11, shows a slightly different view. The original photo was taken from nearly overhead, while the new one comes from a 22° angle east of straight down. It nicely shows the bright band just below the crater's rim, as well as layers on Victoria's steep walls. The band separates bedrock from ejecta deposited by the impact.

Victoria Crater measures 0.5 mile (0.8 km) wide and about 230 feet (70m) deep. Although Opportunity left the crater in August 2008, some of its tracks show faintly on the left side of this photo.

NASA stopped MRO science operations August 26 when engineers found an unlikely but possible vulnerability. It could take several weeks for science to resume. — **R. T.**

Early black holes: smaller and hungrier

The universe's first black holes were tinier and grew more slowly than astronomers thought, according to a recent simulation described in the August 20 edition of *The Astrophysical Journal Letters*.

The simulation showed that before collapsing into black holes, the massive earliest stars shone so brightly that their radiation pushed away nearby gas clouds. This left the eventual black holes with little material to consume. And because black holes produce lots of energy in the form of X-rays, they continued pushing away fuel.

This means the earliest black holes increased their mass by less than 1 percent over 100 million years. Previously, astronomers thought they grew steadily bigger, eventually forming the giant black holes that dwell in the centers of galaxies.

Instead, these giant black holes could be the result of the earliest, starving black holes. Their X-rays could heat gases 100 light-years away, preventing them from coalescing to form a new star and perhaps eventually causing them to form a giant black hole. — **BILL ANDREWS**

QUICK TAKES

IYA SUCCESSOR LAUNCHED

At its August meeting in Rio de Janeiro, the International Astronomical Union announced a decade-long initiative to foster education in astronomy.

MAIN MIRROR FOR MEXICO

The University of Arizona's Mirror Laboratory has begun casting a 6.5-meter mirror, destined for the San Pedro Mártir Observatory in Baja California, Mexico.

HARTMANN A WINNER

For his work on impact cratering and the discovery of the Moon's Orientale impact basin, the Meteoritical Society named William K. Hartmann its 2010 Barringer Medal winner.

COMET AWARDS

The 2009 Edgar Wilson Award for amateur comet discoveries goes to Robert Holmes of the United States, Koichi Itagaki of Japan, Stanislav Maticic of Slovenia, Michael Ory of Switzerland, and Dae-am Yi of Korea. Holmes lives in Charleston, Illinois.

LOST LUNAR SATELLITE

At 1:30 local time on August 29, India lost contact with its Chandrayaan-1 spacecraft. The lunar orbiter mission lasted 312 days and had accomplished about 90 percent of its mission.

EQUINOX UPDATE

On August 10, Saturn and its rings tilted edge-on to the Sun. This marks the first equinox on the ringed planet since November 1995.

CATALINA SURVEY

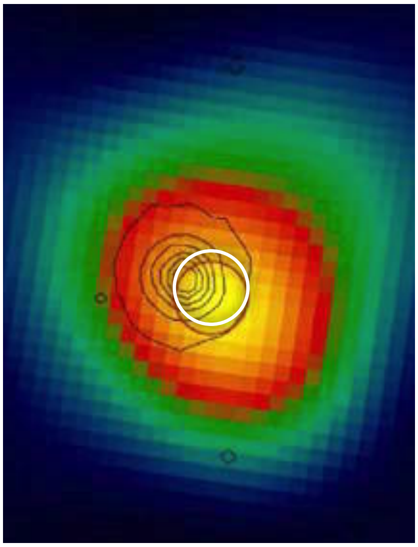
In August, the National Science Foundation awarded Caltech $890,000 to construct a web site making 10 terabytes of Catalina Sky Survey data available to anyone interested.

BLACK HOLE RECORD

University of Hawaii astronomer Tomotsugu Goto and colleagues have discovered a supermassive black hole in a giant galaxy 12.8 billion light-years from Earth.

DON'T BREATHE THE AIR

For the first time, planetary scientists have discovered carbon monoxide in the thin atmosphere of Neptune's moon Triton.



NASA/DOE/Fermi LAT Collaboration

New view. **This Fermi Gamma-ray Space Telescope map shows a gamma-ray signal centered on 47 Tucanae's core (circled in white).**

Gamma rays detected in globular cluster

Astronomers for the first time have detected gamma rays from a globular cluster — a concentration of ancient stars. They think dozens of millisecond pulsars could be responsible for the gamma rays found in 47 Tucanae. The finding, along with two other Fermi Gamma-ray Space Telescope announcements, appeared in the August 14 issue of *Science*.

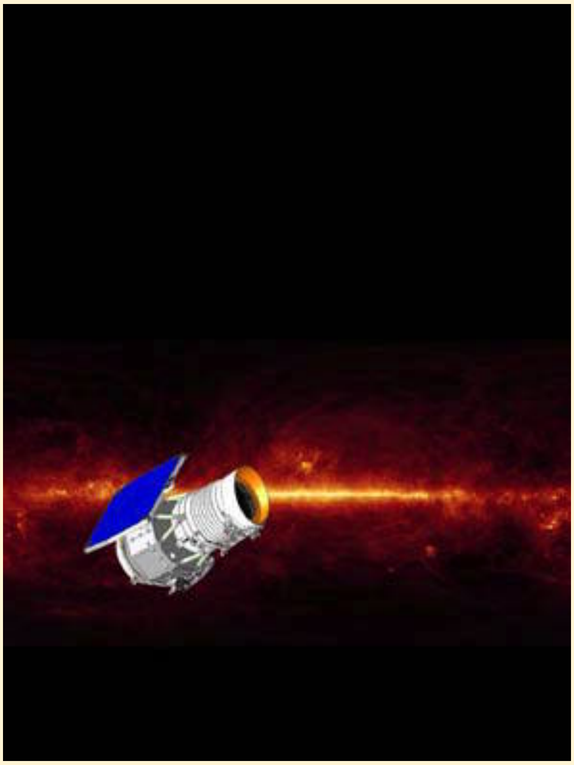
Globular clusters contain hundreds of thousands of stars crammed together. This environment encourages encounters between stars. As material from one star accretes onto an existing pulsar — a highly magnetized, rotating neutron star that beams radiation — the pulsar can "spin up." This creates a millisecond pulsar.

Scientists had long theorized that globular clusters contain many such pulsars. From previous radio and X-ray observations, they knew of 23 millisecond pulsars in 47 Tuc. But they hadn't detected gamma rays from any of those.

After 195.3 days of continuous observations, Fermi detected gamma rays from 47 Tuc. After ruling out a single strong gamma-ray source, the team's most plausible explanation is the cumulative gamma-ray emission from dozens of millisecond pulsars. — **L. K.**

SPACE SCIENCE UPDATE

WISE up in orbit



Heat seeker. **The Wide-field Infrared Survey Explorer (WISE), seen here in an artist's concept, will survey the entire sky following its planned December launch.** NASA/JPL

If all goes according to plan, NASA will launch a new infrared observatory into Earth orbit this December. The Wide-field Infrared Survey Explorer (WISE) will lift off toward a polar orbit from Vandenberg Air Force Base, California. Once it reaches orbit, WISE will scan the entire sky, revealing hundreds of thousands of asteroids and hundreds of millions of stars and galaxies.

Why do scientists need a new infrared observatory? After all, two current spacecraft — NASA's Spitzer Space Telescope and the European Space Agency's Herschel Space Observatory — already observe the cosmos at infrared wavelengths. But both these instruments have relatively narrow fields of view and typically target specific objects. WISE will survey the whole sky.

In this sense, WISE follows in the footsteps of the Infrared Astronomical Satellite (IRAS), a joint mission of the United States, the United Kingdom, and the Netherlands that flew in 1983. Technological advances over the past quarter-century will make WISE hundreds of times more sensitive than IRAS.

WISE consists of a 40-centimeter telescope that will observe the sky at four different infrared wavelengths. As with all infrared telescopes, this one requires a system to cool its onboard detectors so they can record faint radiation and not be swamped by their own heat. WISE will get down to its operating temperature by using frozen hydrogen.

After a 1-month checkout period, WISE will map the sky for 6 months. The frozen hydrogen should last several months longer, enough to survey much of the sky again and notice any changes.

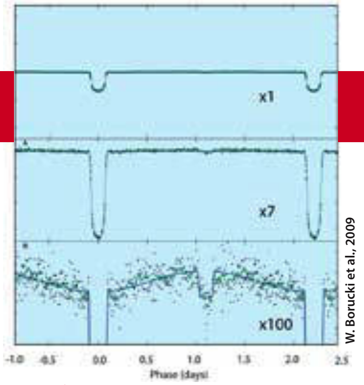
The telescope has a 47' field of view and will achieve a resolution of 6". It will fly in a circular orbit 310 miles (500 kilometers) high.

The all-sky survey will comprise millions of images and serve as a rough map for other infrared observatories such as Spitzer, Herschel, and the future James Webb Space Telescope. "WISE will survey the cosmic landscape in the infrared so that future telescopes can home in on the most interesting properties," says WISE principal investigator Edward Wright of UCLA.

The probe will search both near and far. In our solar system, it will discover hundreds of thousands of new asteroids in the main belt — essentially all of those larger than 1.9 miles (3 km) across. It will also hunt down hundreds of near-Earth objects, those comets and asteroids that pass close to Earth and eventually may pose a threat.

WISE should pick up a wealth of new brown dwarfs farther away. Those objects form like stars but don't have enough mass to ignite nuclear fusion, so they glow dimly and mostly at infrared wavelengths. Our galaxy probably contains more brown dwarfs than stars. Many astronomers think WISE will discover a brown dwarf closer to the Sun than the nearest star, Proxima Centauri, which lies some 4 light-years away.

WISE will find even more distant stellar nurseries, dust-rich planet-forming disks around stars, and the universe's most luminous galaxies. With any luck, 2010 should be a big year for infrared astronomy. — **R. T.**



W. Borucki et al., 2009

Detailed look. Kepler imaged exoplanet HAT-P-7b as it passed in front of ("transited") its star and when the star occulted it. In this data, the bigger dips are transits, and the smaller ones are occultations.

Kepler proves its precision

NASA's Kepler mission has demonstrated that it has the precision to detect Earth-sized planets. Kepler stares at stars and looks for periodic changes in brightness. Those changes could signify a planet passing in front of, or "transiting," the star. Astronomers announced in the August 7 *Science* that Kepler had detected a precise light curve of a known exoplanet's transit and occultation — when the planet passes behind the star.

This find is based on 10 days of data taken shortly after Kepler launched March 6, before the official science operations began.

The planet, HAT-P-7b, orbits its star in 2.2 days at a distance some 26 times closer than Earth is to the Sun. Because of the planet's fast orbit, Kepler observed multiple transits and occultations. In the light curve, the transits' and occultations' depths can tell astronomers about HAT-P-7b's atmosphere. They learned that the atmosphere has a day-side temperature of roughly 4310° Fahrenheit (2380° Celsius). The night side has little of that heat.

From the transit and occultation times, astronomers could also determine that HAT-P-7b has a circular orbit.

The brightness variation Kepler observed is only about 1.5 times that expected from a signal from an Earth-sized planet in an earthlike orbit. This shows great promise for Kepler's next 3 years. — **L. K.**

Streaky sunspots

On August 31, a small spot appeared on the Sun, ending a streak of 51 spotless days. This was the second-longest such streak since 1913.

This planet should not exist

Astronomers who study planets beyond the solar system have been surprised before. But nothing quite prepared them for WASP-18b — an exoplanet so big and close to its host that the star should have swallowed it long ago.

WASP-18b is a "hot Jupiter," a massive planet that orbits within a celestial stone's throw of its parent star's surface. In WASP-18b's case, it has a mass 10 times that of Jupiter and orbits just 1.4 million miles (2.2 million km) from its host, the 9th-magnitude star WASP-18 in the southern constellation Phoenix. The planet completes a circuit around the star every 22.6 hours.

Astronomer Coel Hellier of Keele University in Staffordshire county, England, and colleagues reported in the August 27 issue of *Nature* that the tidal interaction between the star and planet is 10 times stronger than for any other planet known. This means the planet should spiral into the star in less than a million years. Yet, the star appears to be 600 million years old.

Are we seeing WASP-18b at a unique and rare moment? Or does the tidal energy in this system dissipate far more slowly than measured in our solar system and in binary stars?

Astronomers hope to find the answer within the next decade. If we are seeing WASP-18b approaching the end of its death spiral, its period should shrink by an easily detectable 30 seconds in the next 10 years. — **R. T.**

BRIEFCASE

No gravitational waves, no problem

Scientists with the Laser Interferometer Gravitational Wave Observatory (LIGO) installations in Livingston, Louisiana, and Hanford, Washington, report that they've found nothing. This lack of gravitational waves is what they hoped to find, as it helps them narrow down what the universe was like in its earliest moments. Gravitational waves are theoretical ripples in the fabric of space-time, created by extremely powerful events. The results appeared in *Nature*'s August 20 issue. — L. K.

Interstellar wind warps dust disks

Astronomers reported in the September 1 issue of *The Astrophysical Journal* that they've discovered a mechanism to account for the warped debris disks around some stars. As the star — with its disk and forming planets — travels through the galaxy, it interacts with interstellar gas. "The small particles slam into the flow, slow down, and gradually bend from their original trajectories to follow it," says John Debes of NASA's Goddard Space Flight Center. — L. K.

Speedy stars raise some questions

Stars 11 billion light-years away are racing around their galaxy at extraordinary speeds — some 1 million mph (1.6 million km/h). Such speeds imply the galaxy has a large mass crammed into a small volume. Astronomers aren't sure how such compact, massive galaxies formed and why they're not present in today's universe. The finding was published in the August 6 *Nature*. — L. K.

25 years ago in *Astronomy*

ASTRONOMY
Race to the Moon: the Soviet Story

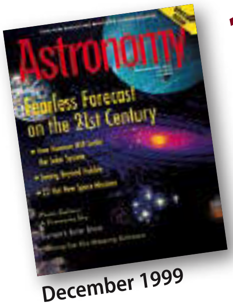
December 1984

In the December 1984 issue of *Astronomy*, freelance writer Peter Pesavento gave an in-depth report on the space race in "Soviets to the Moon: the Untold Story."

Pesavento focused on various Soviet missions that showed their technological progress and that they truly had their eyes on landing on the Moon's surface. Some of the specifics he gave included Aleksei Leonov's spacewalk in which he somersaulted in space for 10 minutes. That was in March 1965. A United States lunar suit wasn't flight tested until March 1969.

Pesavento also discussed the question of why the Russians still haven't landed on the Moon. The most likely answer seems that they "saw little fame or glory in being the second nation to put men on the Moon."

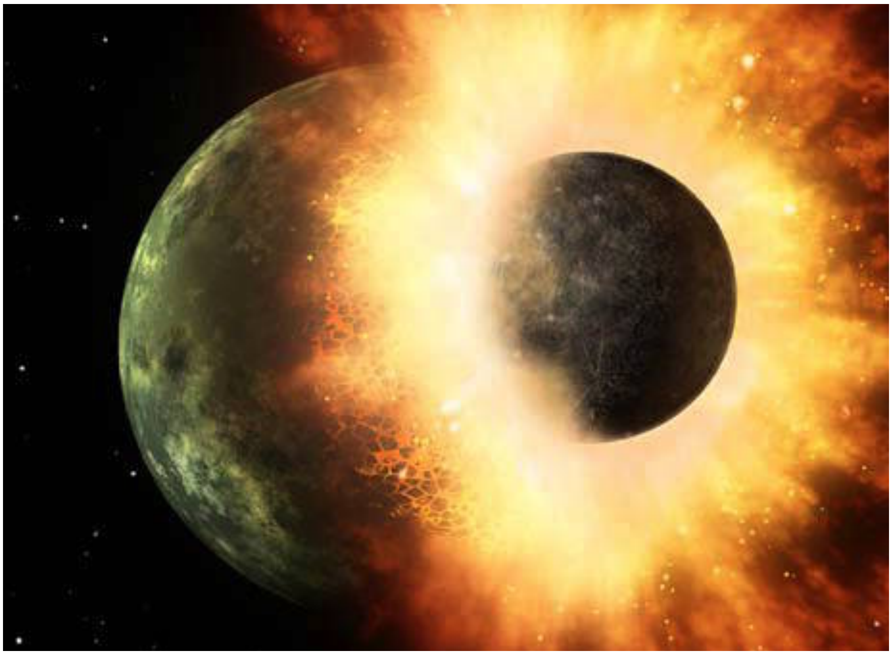
10 years ago in *Astronomy*



December 1999

The December 1999 issue of *Astronomy* featured six articles about astronomy's future in "Forging the future." The articles, from a variety of writers, focused on topics such as the search for life on exoplanets, giant ground-based telescopes, and sending humans off planet Earth.

As the last *Astronomy* edition of the 1900s, the December 1999 issue also juxtaposed what the 21st century will bring against what astronomers had accomplished in the 20th century. — **L. K.**



High-speed collision. A Moon-sized body slams into an object as large as Mercury in this illustration. Debris is vaporized and flung out from the collision. NASA/JPL-Caltech

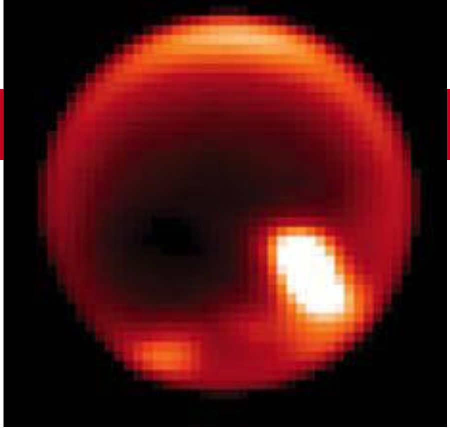
Spitzer sees products of planetary collision

The Spitzer Space Telescope has seen the aftermath of a high-speed collision between two young rocky planets. It appears the collision occurred within the last few thousand years around a young star some 95 light-years away. The finding appeared in the August 20 issue of *The Astrophysical Journal*.

Spitzer analyzed the light of star HD 172555 to look for chemical signatures. The astronomers identified silicon monoxide gas (evidence of vaporized rock) and amorphous silica (evidence of melted rock).

They think two rocky bodies — one the Moon's size or larger and the other at least Mercury's size — slammed into each other. The high-speed impact (at least 22,000 mph [36,000 km/h]) vaporized rocky surfaces and sent plumes of hot matter into space. The impact likely stripped the larger body of its outer layers and also absorbed the smaller planet's core into the larger body.

Astronomers say an impact like this may have been what stripped Mercury of its outer crust. — **L. K.**



Storm cloud. Titan's unexpected clouds, the bright area in the lower right, appeared in an area previously thought incapable of producing clouds. Gemini Observatory/AURA; E. Schaller et al.

Storms pop up on Titan

Astronomers had thought the tropical deserts of Saturn's moon Titan were too dry to form clouds, but a paper in the August 13 *Nature* proves the opposite. Emily Schaller of the University of Hawaii and colleagues describe a large system of storm clouds started by something like a mid-latitude cloud explosion. This system set off waves that triggered more clouds around the planet. The south pole quickly disappeared behind them, and bright, transient clouds went up to the equator.

Exactly what started this activity remains unknown, as does much of Titan's weather, because astronomers have been studying it only recently. With a titanian year lasting 30 Earth years, fully understanding Titan's weather now would be as difficult as fully understanding Earth's after only 2 months of data.

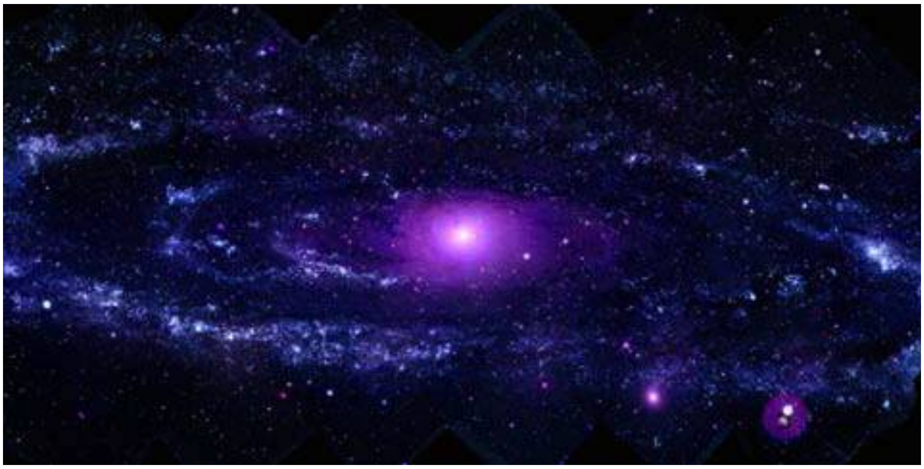
These recent storms may help explain how rivers and streambeds could form in such a dry region. One theory is that possible liquids seep up from the ground, but it now seems more likely that uncommon but strong downpours may be the cause, just like in much of the American Southwest. — **B. A.**

New UV view of M31

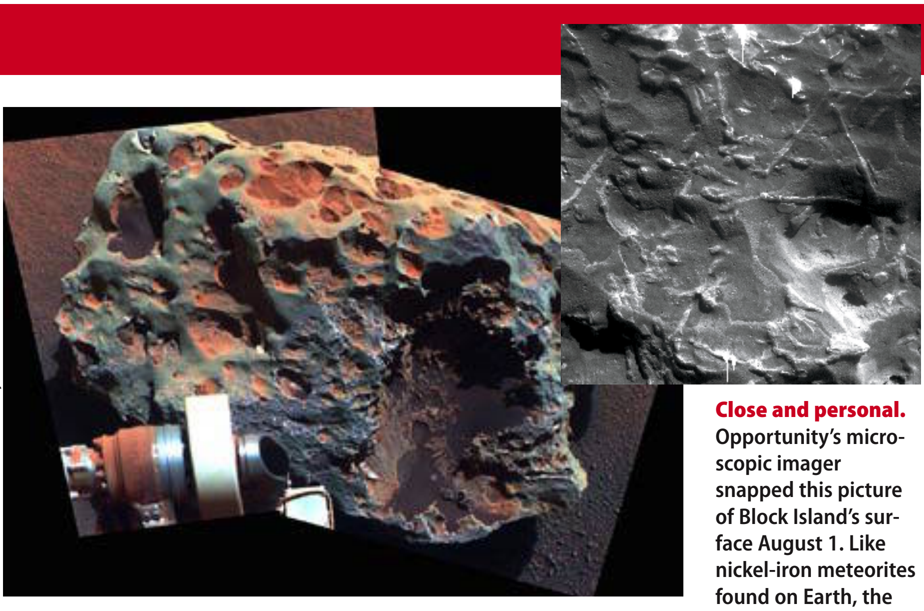
Combine 24 hours of observations in three different ultraviolet (UV) filters, and you get the most detailed UV view ever of the Andromeda Galaxy (M31). NASA released the Swift Ultraviolet/Optical Telescope image of the spiral galaxy nearest to the Milky Way September 15.

Young stars emit lots of UV radiation, whereas older stars do not. This is evident in the Swift image. Older stars make up M31's core, and in the image they exhibit a red-purple color. There are very few new stars in the core because it lacks much of the material needed to create stars.

The spiral arms, however, are sites of young stars. These regions show up blue, and even white in some areas, in the image. — **L. K.**



Through UV eyes. This Swift composite image contains about 20,000 ultraviolet sources and includes 330 images in three different filters. NASA/Swift/Stefan Immler (GSFC) and Erin Grand (UMBC)


NASA/JPL-Caltech/Cornell University

NASA/JPL-Caltech/Cornell University/USGS

Close and personal. Opportunity's microscopic imager snapped this picture of Block Island's surface August 1. Like nickel-iron meteorites found on Earth, the rock shows a triangular pattern of small ridges (upper right).

Block Island. This watermelon-sized rock, dubbed Block Island by planetary scientists, is the largest meteorite ever discovered on Mars. The Opportunity rover's robotic arm appears at the lower left on this false-color image.

Paradise on Block Island

To solar system aficionados, Block Island is more than a picturesque piece of land off the southern shore of Rhode Island. "Block Island" is also the name planetary scientists bestowed on the largest meteorite yet found on the surface of Mars.

NASA's Mars rover Opportunity took a picture of this roughly watermelon-sized meteorite in late July, then stored it in its computer. Once Opportunity sent the picture of the bluish rock to Earth, scientists realized they might have something special. So in early August they sent the rover back to examine the meteorite in detail. Opportunity's alpha particle X-ray spectrometer confirmed the object is a nickel-iron meteorite.

Block Island might have a lot to say about the history of Mars' atmosphere and climate. It weighs too much to have passed through the current thin atmosphere and landed without disintegrating. So, it must have landed long ago, when Mars' thicker atmosphere would have slowed it considerably. Scientists hope the marks on the meteorite's surface will reveal how the martian climate affected it over the years. — **B. A.**

Comet harbors life's building block

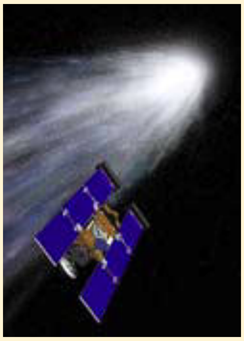
Scientists have long suspected that the fundamental building blocks of life exist in space. Now they have proof. Samples of Comet Wild 2 returned to Earth by NASA's Stardust spacecraft show the unmistakable presence of the amino acid glycine.

"Glycine is an amino acid used by living organisms to make proteins, and this is the first time an amino acid has been found in a comet," says Jamie Elsila of NASA's Goddard Space Flight Center in Greenbelt, Maryland. Elsila presented the findings August 16 at a meeting of the American Chemical Society in Washington, D.C.

Stardust flew through the gas and dust surrounding Comet Wild 2's icy nucleus January 2, 2004. Special aerogel collectors captured samples, and the spacecraft returned them to Earth in January 2006.

Because terrestrial life uses glycine, earlier researchers didn't know if the glycine might be earthly contamination. But Elsila's team found the glycine's carbon-isotope abundances matched those in space.

The glycine detection adds to the debate over life's origin. "Our discovery supports the theory that some of life's ingredients formed in space and were delivered to Earth long ago by meteorite and comet impacts," says Elsila. — **R. T.**



Sticky fingers. Aerogel collectors on the Stardust spacecraft captured the amino acid glycine when it flew through the gas and dust surrounding Comet Wild 2. This artist's illustration shows Stardust's closest approach in January 2004. NASA/JPL

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— Phil Harrington, *Astronomy Magazine*, August 2009

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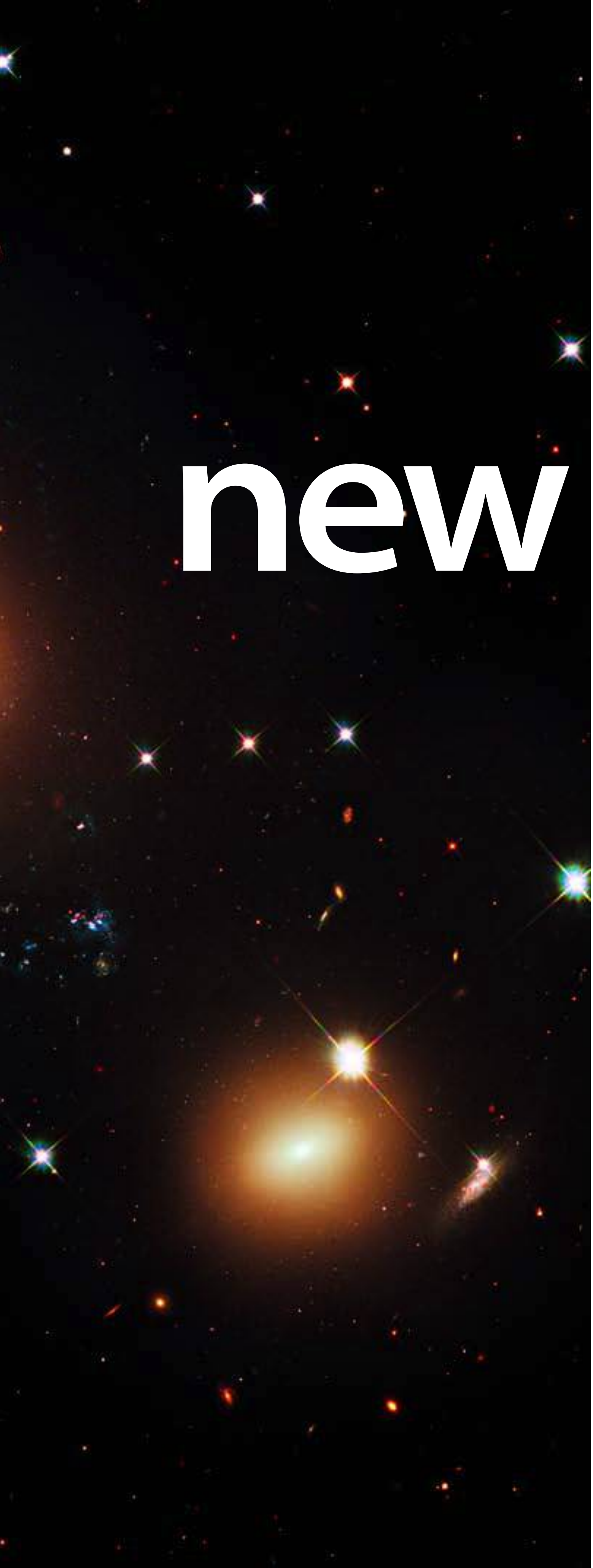


Hubble's grand new vistas

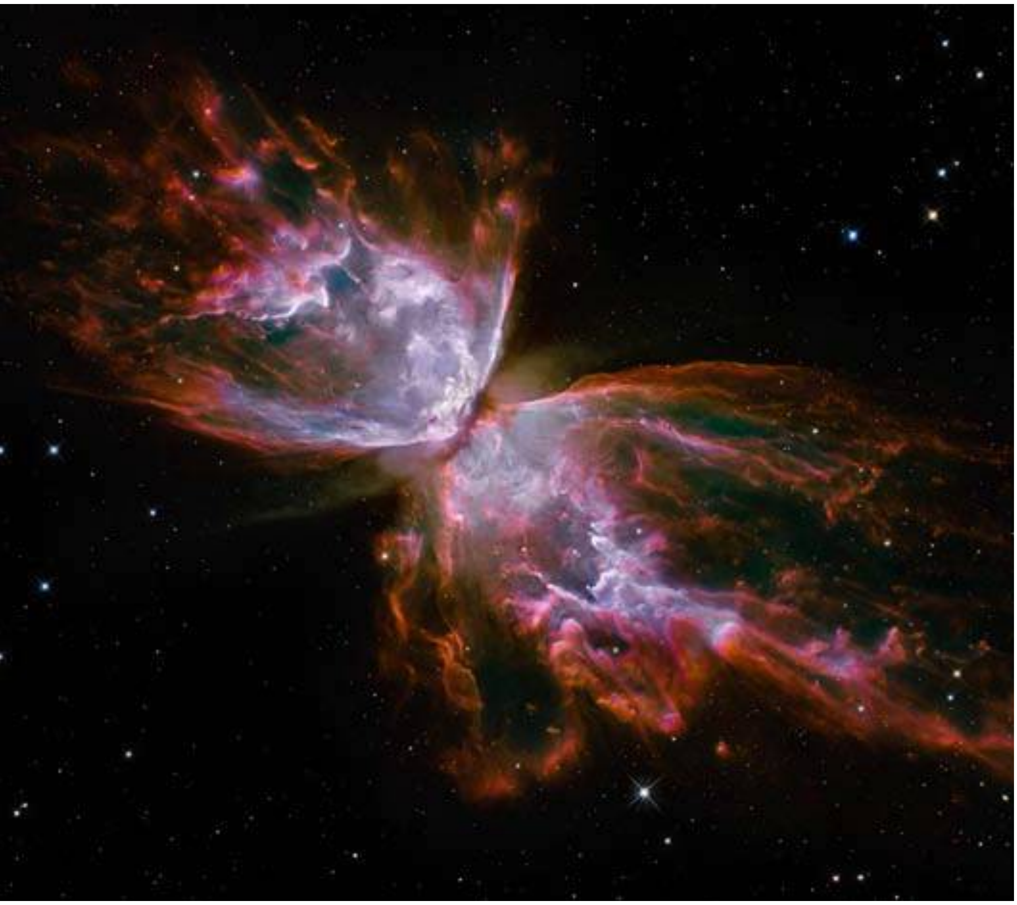
Early results from the space telescope's new camera and spectrograph prove there's a lot of life left in the aging observatory. **by Richard Talcott**

September 9 was a special day for number-lovers, as the calendar page turned to 09/09/09. For astronomers and everyone else who loves the night sky, the 9th proved even more auspicious. It was the day we got our first peek at how the recently refurbished Hubble Space Telescope now performs. No one was disappointed.

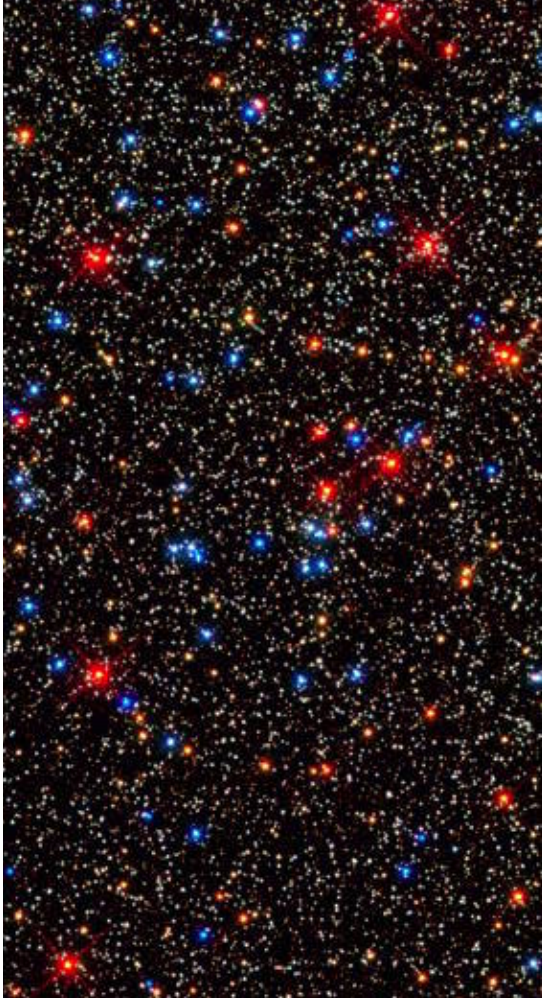
"We're giddy with the quality of data," says Heidi Hammel of the Space Science Institute in Boulder, Colorado. Hammel led the team that made the first science observations with Hubble following May's servicing mission. She convinced NASA to interrupt the orbiting observatory's recommissioning to view Jupiter after a comet or asteroid unexpectedly smashed into the giant planet in mid-July.

The servicing mission "left Hubble as a new, state-of-the-art observatory," claims Ed Weiler, an associate administrator at NASA Headquarters in Washington,

Stephan's Quintet reveals its true identity as a group of four plus one in this WFC3 image combining visible and infrared observations. The four yellowish galaxies include three spirals (top left and two at center) with distorted shapes and elongated spiral arms, signs of ongoing encounters, along with a normal elliptical (lower right). The bluish galaxy at lower left shows individual stars because it lies only 40 million light-years from Earth, some 7 times closer than the others. All images: NASA/ESA/The Hubble SM4 ERO Team



The Bug Nebula looks more like a butterfly in this WFC3 image. This planetary nebula shows what happens when a star some 5 times more massive than the Sun nears the end of its life. The star's tenuous outer layers were blown off in several episodes during the past 2,200 years and created the butterfly's wings, which now span more than 2 light-years. The dying star lies hidden by a thick dust ring at the nebula's center.



D.C. The seven-member crew of the space shuttle *Atlantis* not only installed two new instruments — the Wide Field Camera 3 (WFC3) and the Cosmic Origins Spectrograph (COS) — but also repaired two others — the Advanced Camera for Surveys (ACS) and the Space Telescope Imaging Spectrograph (STIS).

The new camera debuts

The results of the astronauts' efforts were on display September 9. University of Virginia astronomer Bob O'Connell, who chairs WFC3's science oversight committee, says WFC3 "works better than we expected." And expectations were high to begin with.

The camera's initial targets included a compact group of galaxies known as Stephan's Quintet, the crowded central regions of the massive globular cluster Omega Centauri, a region of active star formation in the Carina Nebula, and the wispy tendrils of a dying Sun-like star in the Bug Nebula.

Besides choosing an array of different subjects, astronomers picked objects that showcase the new camera's capabilities. WFC3 has two channels: one that views the cosmos at visible and ultraviolet wavelengths and one that captures near-infrared radiation. So, the camera can record hot objects (bright in ultraviolet), cool objects (bright in infrared), and those in between (brightest at visible wavelengths) at the same time. WFC3 already has become Hubble's new workhorse. Half of the telescope's observations in the next year will use this camera.

While WFC3 records light to create pictures, COS breaks down light into its constituent colors. The resulting spectrum reveals an object's temperature, composition, density, and velocity. COS operates about 10 times more efficiently than its predecessors on Hubble, which means that in the same length of time, it can observe 10 times as many objects — or objects one-tenth as bright.

For the first spectral observations, scientists targeted supernova remnant N132D in the Large Magellanic Cloud, active galaxy Markarian 817, and quasar PKS 0405–123. The quasar observation spotlights one of COS's primary tasks.

Astronomers use quasars to probe the "cosmic web" — the long, narrow filaments of galaxies and diffuse gas that populate the intergalactic medium. Because each filament lies at a different distance from Earth, cosmic expansion shifts its spectral fingerprint by a different amount. In looking at PKS 0405–123, which lies 7 to 8 billion light-years from Earth, researchers detected nearly 5 times as many hydrogen-gas filaments along this line of sight.

New life for old equipment

Although astronomers felt undeniable excitement over the first results from the new instruments, they also were happy to see a return to life for some old

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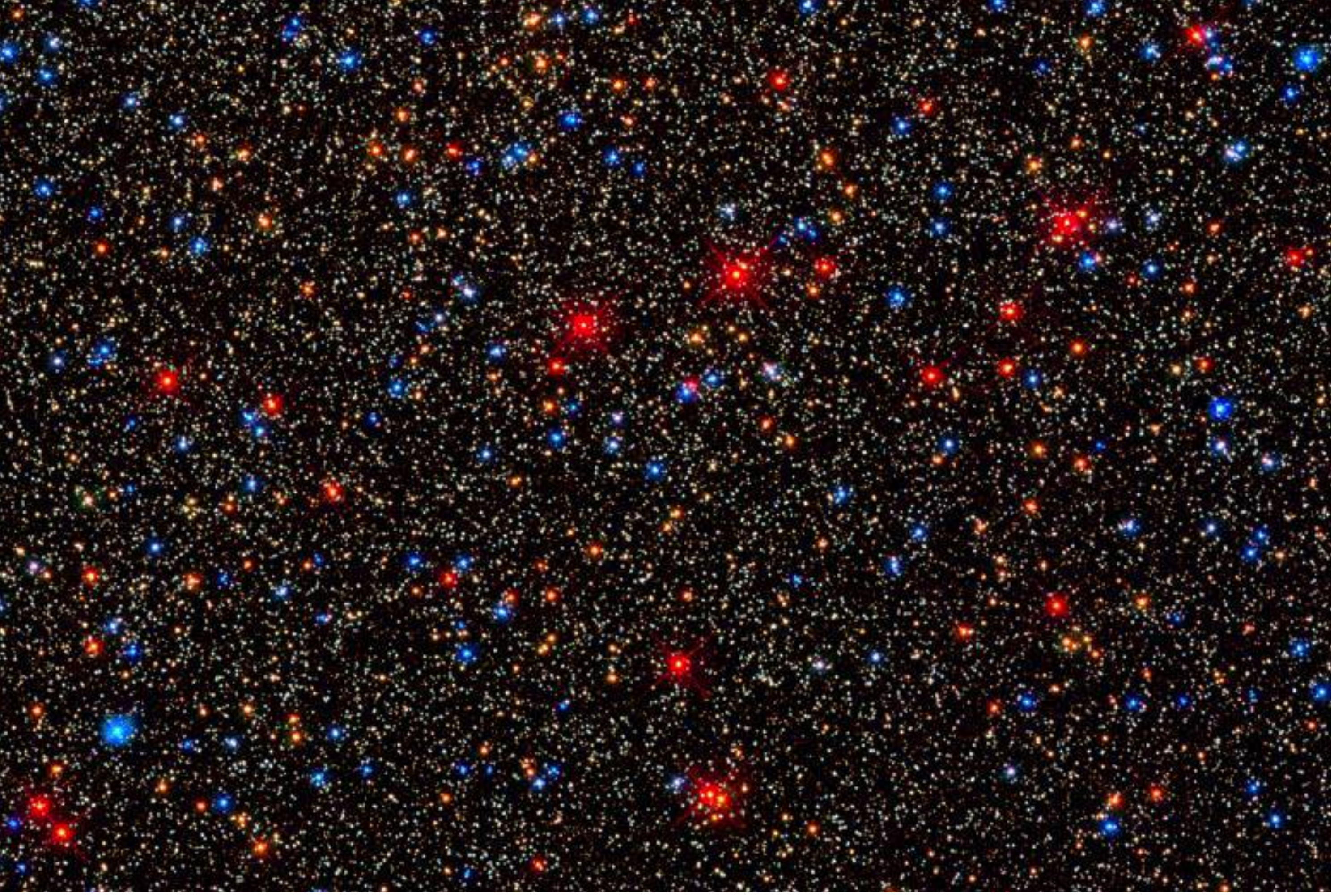
Richard Talcott *is a senior editor of* Astronomy. *He is the author of* Teach Yourself Visually Astronomy *(Wiley Publishing, 2008).*



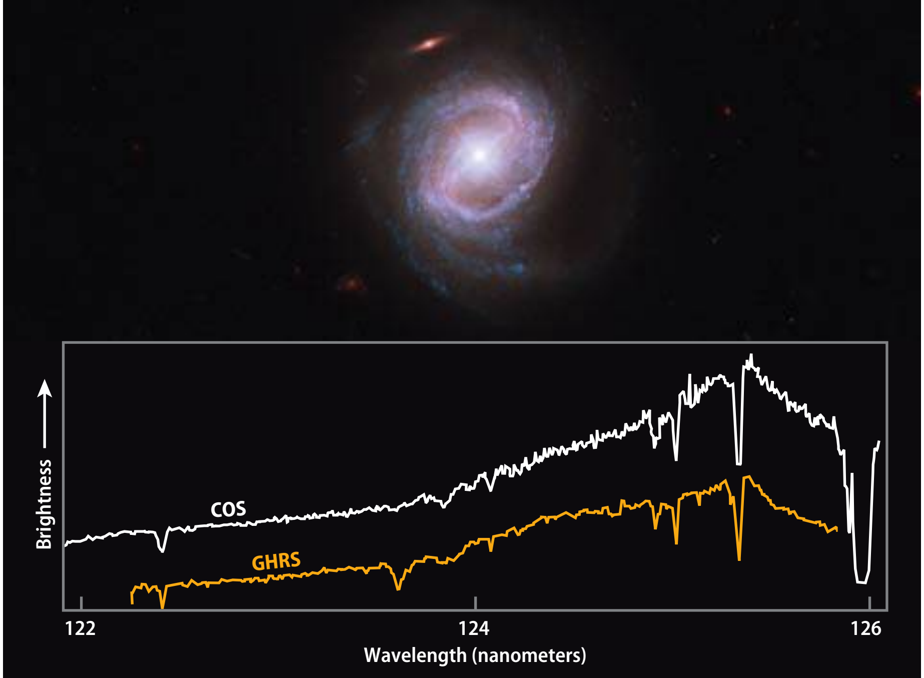
Globular cluster Omega Centauri contains nearly 10 million stars that formed more than 10 billion years ago. This WFC3 image shows the inner 12 light-years, home to some 100,000 stars. Still, Hubble resolves them all. The color contrast here is real. Most of the stars are yellow, like the Sun, and fuse hydrogen into helium. The red stars are more evolved giants that have expanded and cooled. And the blue stars have evolved even further, shedding their outer layers and glowing strongly in the ultraviolet.

friends. STIS stopped working in 2004 and ACS in 2007, the results of separate electronics failures.

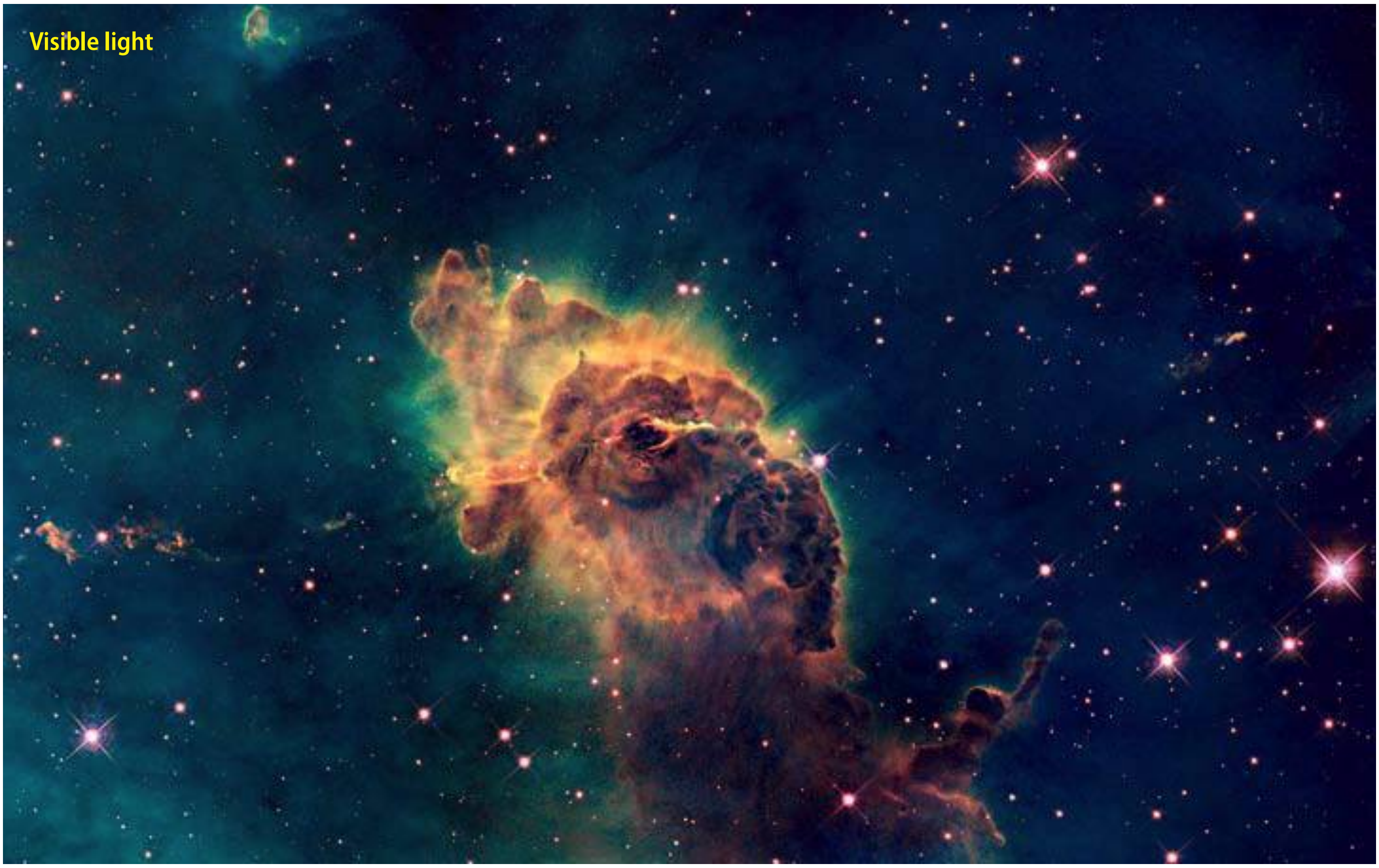
NASA didn't design either instrument to be fixed in orbit. Scientists kept their fingers crossed that the spacewalking astronauts would manage to get one functioning again, but both are working great. These repaired instruments will complement observations made with the new camera and spectrograph.

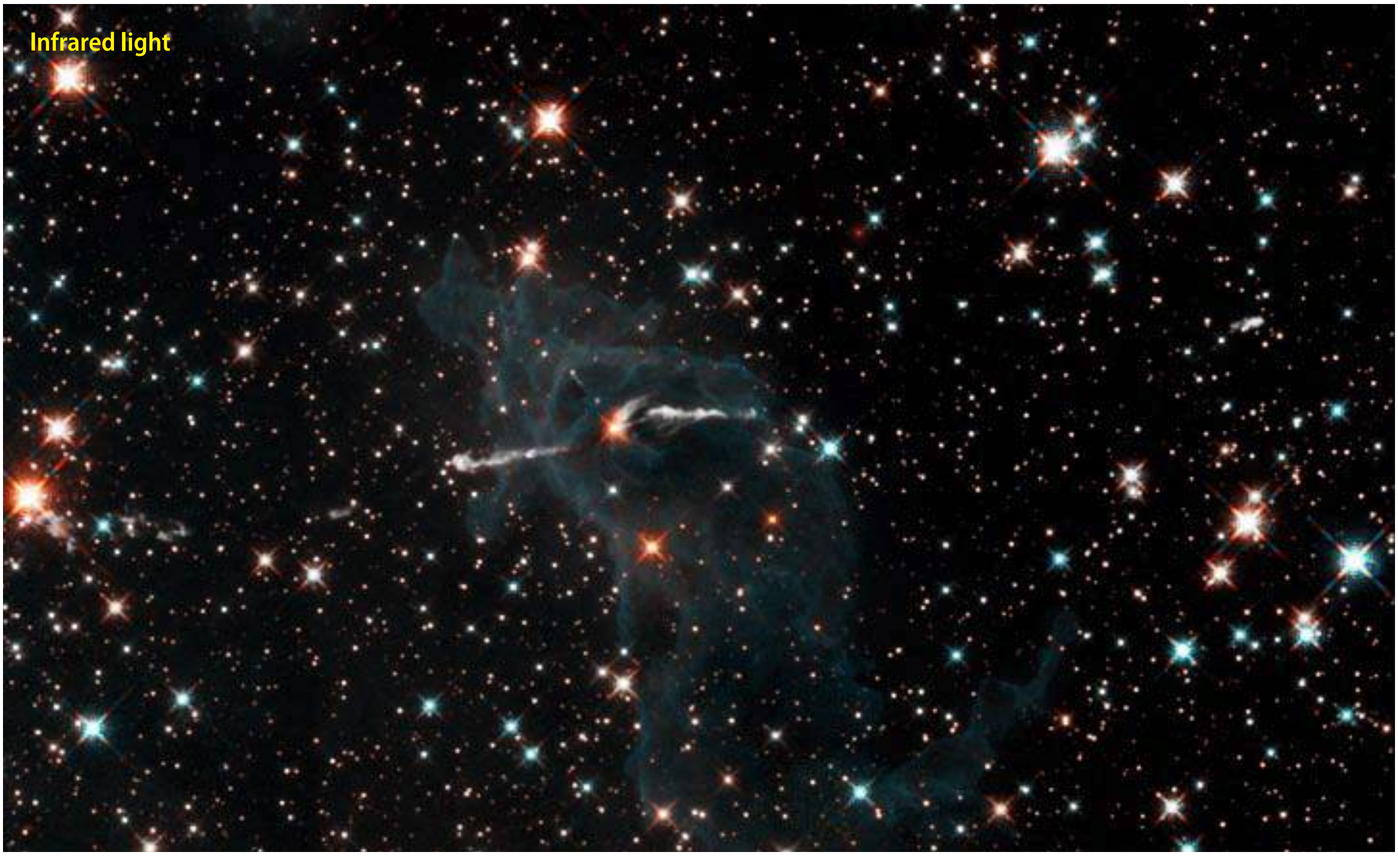
A fifth instrument — the Near Infrared Camera and Multi-Object Spectrograph (NICMOS) — also appears to be returning to life. Mission controllers had to shut down the instrument's cooling system while making a computer upgrade in September 2008. But the system stubbornly refused to restart. In

Active Galaxy Markarian 817

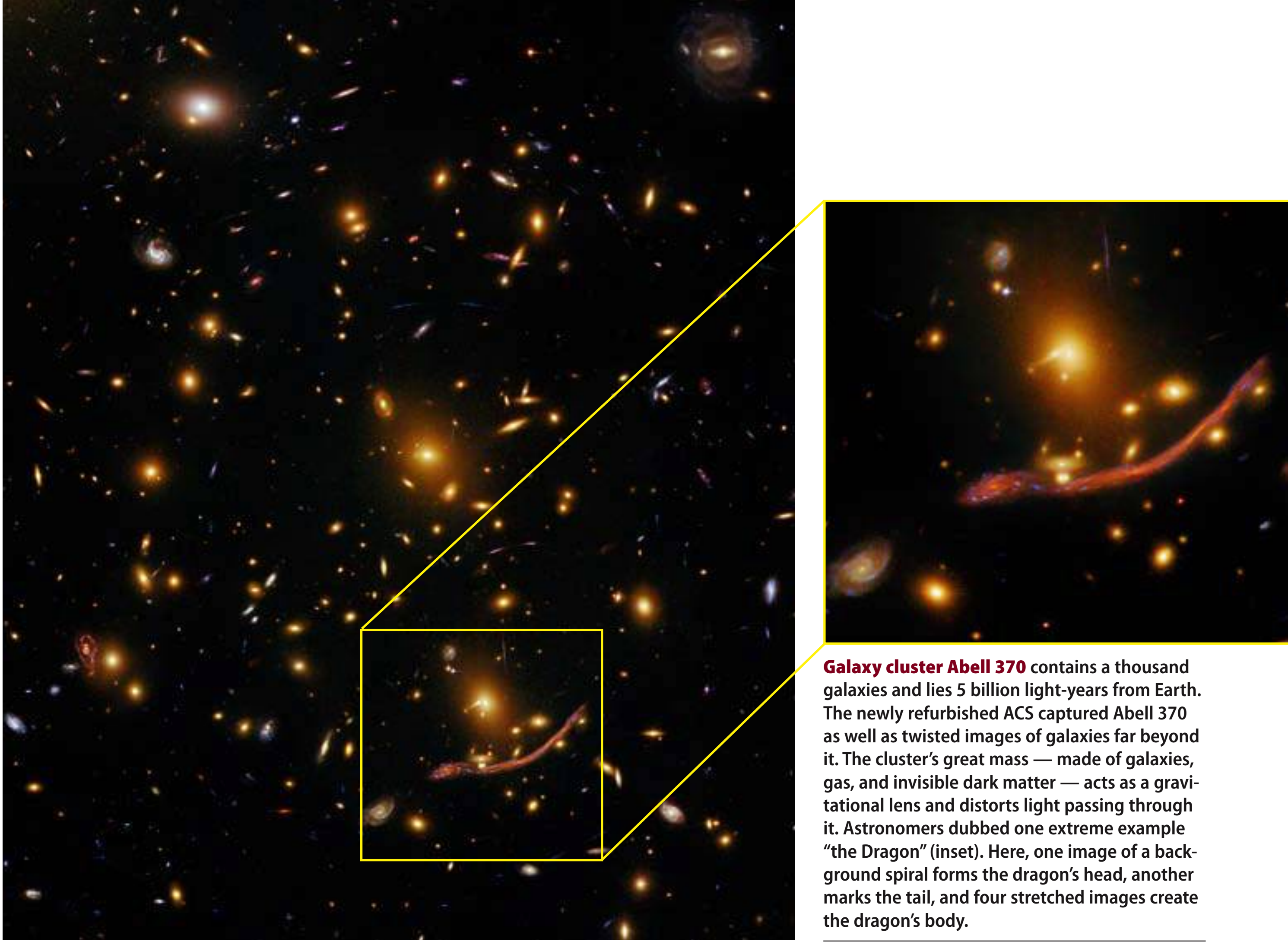


Active galaxy Markarian 817 shows off the expanded capabilities of the new COS instrument. This view compares a COS spectrum with that from one of its predecessors, the Goddard High Resolution Spectrograph (GHRS). COS is 10 times more sensitive than GHRS, so it records more light and has a higher signal-to-noise ratio. This view also shows all the wavelengths captured by GHRS but only one-eighth of those COS records. WFC3 photographed the galaxy (top).





The Carina Nebula holds many wonders, including a 3-light-year-long pillar of gas and dust seen here in two different wavelength ranges. In visible light (top), WFC3 captures the pillar's tip. Massive stars (located off the top of this image) evaporate some of its gas, creating the greenish streamers. The big stars also compress the gas, triggering star formation. In infrared light (above), WFC3 penetrates the gas and dust, revealing some of these fledgling stars. High-speed jets spurt from one of those stars at speeds up to 850,000 mph (1.4 million km/h).



Galaxy cluster Abell 370 contains a thousand galaxies and lies 5 billion light-years from Earth. The newly refurbished ACS captured Abell 370 as well as twisted images of galaxies far beyond it. The cluster's great mass — made of galaxies, gas, and invisible dark matter — acts as a gravitational lens and distorts light passing through it. Astronomers dubbed one extreme example "the Dragon" (inset). Here, one image of a background spiral forms the dragon's head, another marks the tail, and four stretched images create the dragon's body.

August, however, engineers got it going, and the cooling system was bringing NICMOS down to its operating temperature of –321° Fahrenheit (–196° Celsius).

Worth the long wait

The shuttle astronauts released Hubble in May. That's when engineers and scientists on the ground got to work. They spent the summer making sure all of the telescope's instruments worked the way they were supposed to.

The Servicing Mission Observatory Verification (SMOV in NASA-speak) took months to complete because the ground team had so much to do. The first task: Make sure Hubble could point accurately. The *Atlantis* astronauts replaced all six of Hubble's gyroscopes. Engineers calibrated the gyroscopes by changing Hubble's orientation in a precise way and then looking at the data they generated.

Getting the new instruments up to speed took even longer. First, both WFC3 and COS had to "outgas" — release the extraneous atoms and molecules that arise naturally from being built on Earth. The instruments use high-voltage power, and stray gases conduct electricity, which could cause a short circuit and ruin the instrument. To prevent this, engineers raised the voltage slowly and checked the circuitry at each stage.

Stray gases also absorb light at certain wavelengths. So, any such gases left in the instrument would reduce the instruments' sensitivity and impart their own spectral fingerprints.

Next, engineers had to align and then focus both WFC3 and COS, which were weightless and in the vacuum of space for the first time. The ground team accomplished this by using tiny mirrors and other mechanisms built into the instruments. The process took a few weeks for each.

Finally, scientists and engineers calibrated the instruments. Each scientific observation includes data both from the sky and from the instrument. By viewing a familiar astronomical object, scientists can compare what should be visible with what they actually see. Then, they either adjust the instrument or, more often, set up computer processing on the ground to remove these "instrument signatures."

Digging deeper and farther

Now that Hubble is operating at a higher level than ever before, astronomers anticipate all its new discoveries. Among the first observations scheduled is another Hubble Ultra Deep Field. WFC3 will take this image in the infrared, and it promises to be the deepest view ever of the cosmos. Some researchers expect it to turn up galaxies within 500 million years of the Big Bang.

Hubble now has the capability to observe the atmospheres of some exoplanets. Such observations should reveal the compositions of these atmospheres, perhaps even those of earthlike planets that the Kepler mission will locate.

Hubble has built an outstanding legacy during its first 19 years in orbit. It appears destined to add more superlatives in the years ahead.

Ghost particles

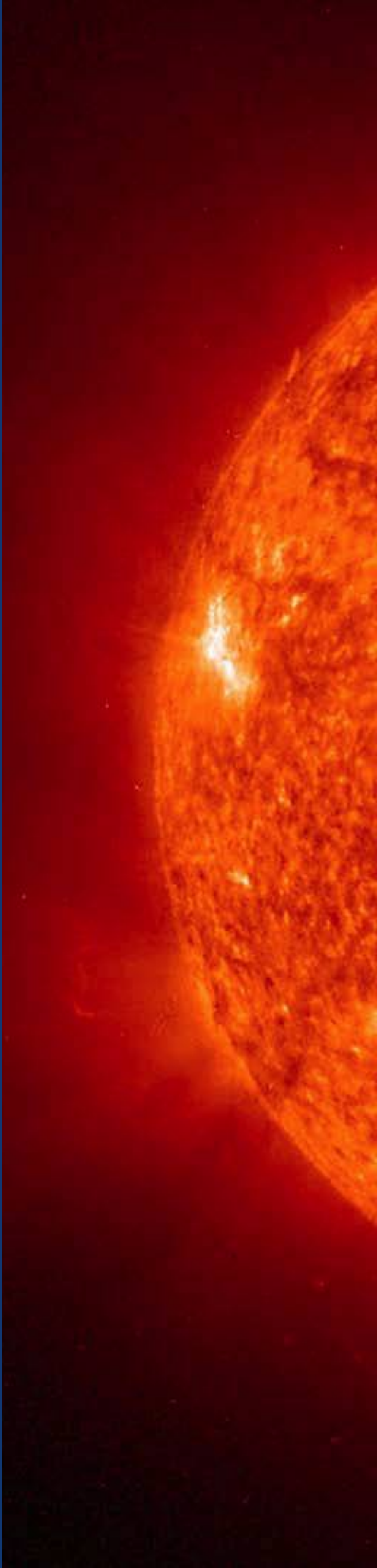
What can **neutrinos** tell us about the universe?

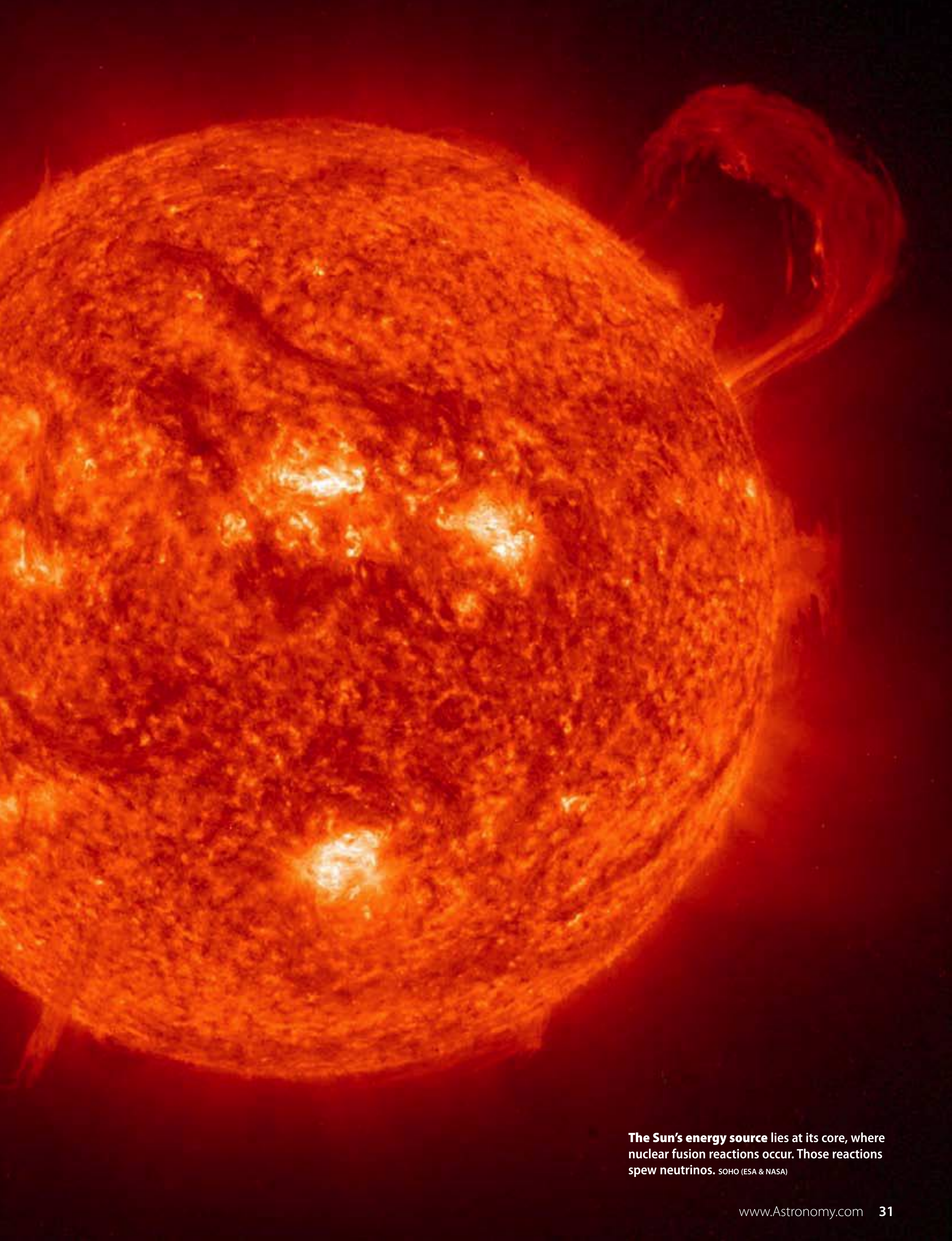
Astronomers are studying subatomic particles from supernovae and other energetic phenomena, but such particles are difficult to detect. **by James Trefil and Wanda O'Brien-Trefil**

We learn about the universe by looking at the heavens, which means our knowledge depends on the kinds of signals we see and the messengers that bring them to us. The messenger that we've studied since ancient times is, of course, light.

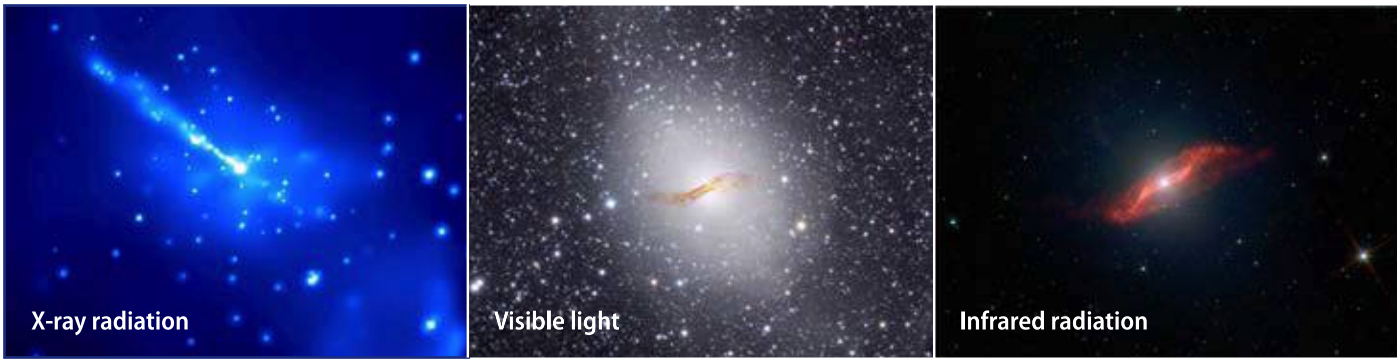
Our ancestors were able to detect visible light with their naked eyes and eventually telescopes. But that gave them only one window to the sky. In the 20th century, we opened many new windows after we built radio telescopes on Earth and launched satellites carrying detectors above the atmosphere. Infrared data showed the cool gases that run through our galaxy, and violent explosions in distant galaxies announced their presence as high-energy gamma rays. Radiation carries information about the regions from which it was emitted. But our atmosphere absorbs most radiation other than visible light and radio waves.

All our terrestrial and satellite observatories have one thing in common: They detect radiation that is part of the electromagnetic spectrum. But there is a new window that astronomers





The Sun's energy source lies at its core, where nuclear fusion reactions occur. Those reactions spew neutrinos. SOHO (ESA & NASA)



Active galaxy Centaurus A looks different depending on what radiation window you observe it in. In X-rays (left), the most prominent feature is a high-energy jet. Optical light (center) shows off the elliptical galaxy's thick dust lane. Mid-infrared (right) shows more detail of the dust structure. X-ray: NASA/SAO/R.Kraft et al.; Optical: Michael Sidonio; Infrared: NASA/JPL-Caltech/J. Keene (SSC/Caltech)

are opening — one that doesn't depend on electromagnetic waves, but on a messenger from the heavens in the shape of an elusive particle called a neutrino.

The mysterious neutrino

A neutrino is one of the particles that such processes as radioactive decay and nuclear fusion produce. It has no electric charge, virtually no mass, and interacts so weakly with matter that a single neutrino could pass through a layer of lead light-years thick without disturbing a single atom.

In the early 1900s, when physicists added up the energy and momentum before and after a particular radioactive decay, they found that the books didn't balance. Austrian physicist Wolfgang Pauli in 1930 suggested that an undetected particle carries away the missing energy and momentum. Scientists gave that hypothetical particle the name "neutrino" (which means "little neutral one").

Because it interacted so weakly with matter, however, the neutrino was almost impossible to detect. In fact, it wasn't until 1956 that physicists, working with a flood of neutrinos emitted from a nuclear reactor, detected a minute fraction of the particles jostling atoms on their way into space. (Frederick Reines received the 1995 Nobel Prize in physics for this work.) Since then, physicists have gotten a lot better at both detecting and producing these elusive particles.

What does this have to do with astronomy? Well, many of the most important processes in the heavens — from the fusion reactions that power stars to the supernovae that produce the heavy elements — involve nuclear reactions that emit neutrinos as a byproduct. In fact, the universe is flooded with neutrinos. You can think of them as another messenger — this one carrying information about all the nuclear reactions, mundane and violent — that marks the natural world.

Two-faced

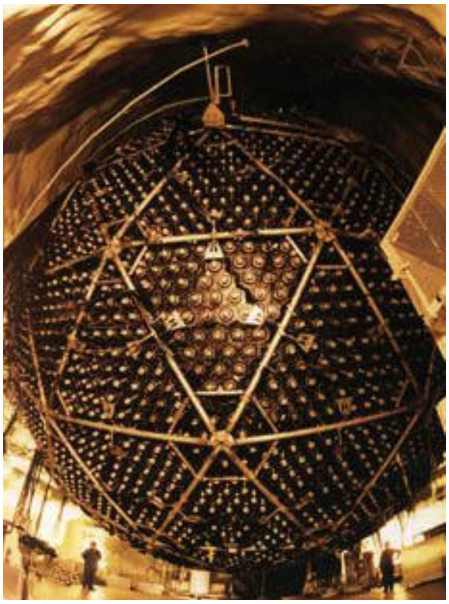
The elusiveness of neutrinos is actually a classic good news-bad news situation. On one hand, neutrinos' reluctance to interact with matter means they can escape easily from the region where they form and carry their messages to us. Neutrinos produced by fusion reactions in the Sun's core, for example, can travel through the outer solar envelope and Earth's atmosphere unscathed. Detecting them allows us to see into the heart of our star.

Also, neutrinos can travel intergalactic distances without interacting with the microwave radiation that fills the universe. Galactic magnetic fields don't affect them, which is not true for ordinary (and charged) particles such as protons and electrons. These qualities make neutrinos the ideal medium for carrying information about the most violent phenomena in the universe. Such things include active galactic nuclei or the mergers of black holes that some astronomers believe produce a type of gamma-ray burst, the most energetic blast in the universe.

That's the good news. The bad news is that detecting neutrinos is devilishly hard.

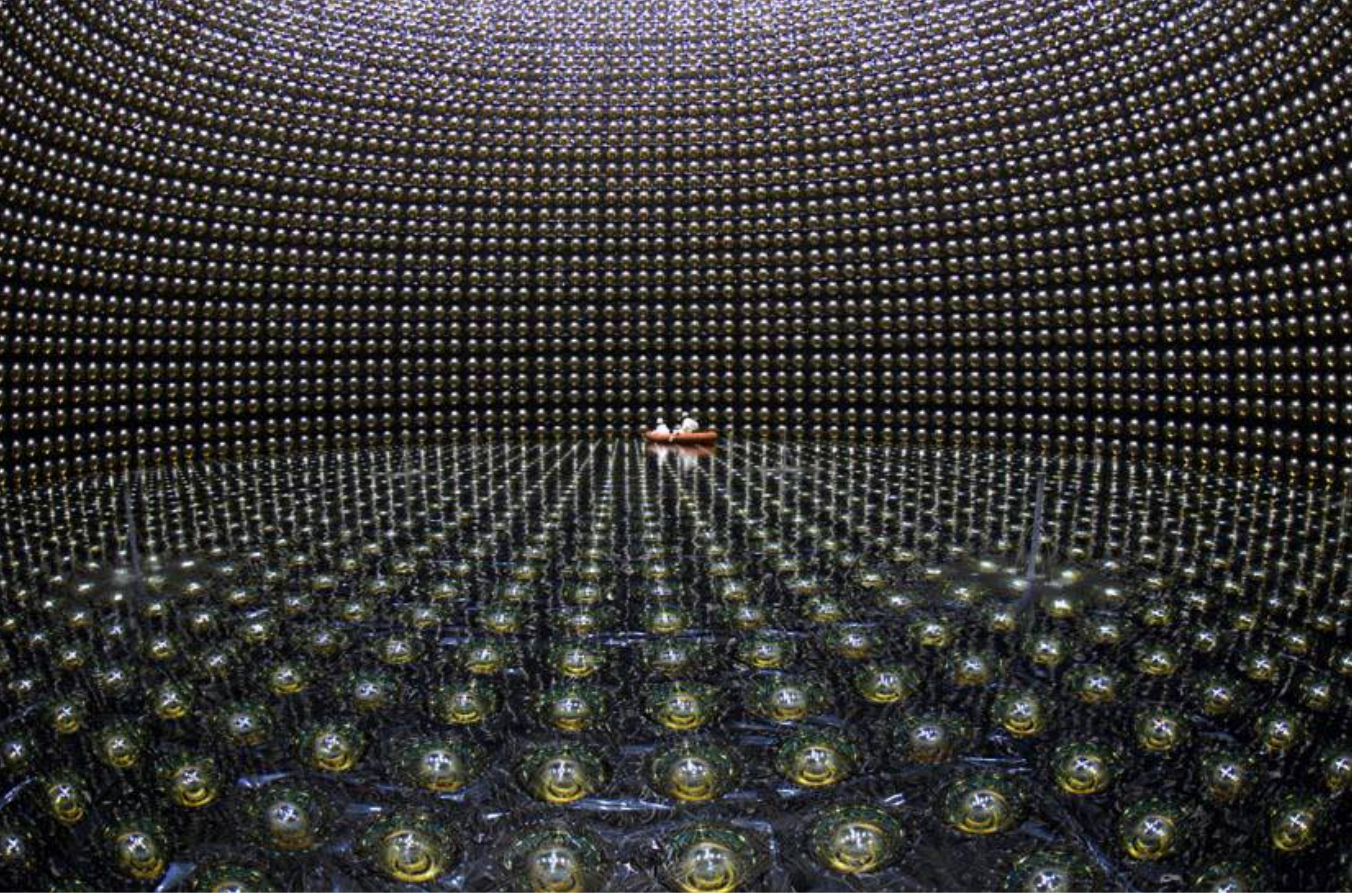
As you read these words, literally billions of neutrinos are passing through your body. Most come from the Sun, but some hail from distant galaxies, and some may even be echoes of the Big Bang. Neutrinos have passed through you ever since you were born, yet in your entire lifetime only a handful of those neutrinos will actually betray their presence by interacting with atoms in your body. Detecting those interactions and distinguishing them from what else perturbs your atoms is the central task in the field of neutrino astrophysics.

If we want to look at the sky through the neutrino window, we must solve two problems. We've already discussed the obvious one: the reluctance of neutrinos to interact with matter. There is a simple way to deal with this. If a neutrino has a low probability of interacting with a given atom, put lots of atoms into a large detector so interactions become more frequent.


Courtesy Ernest Orlando Lawrence Berkeley National Laboratory

The Sudbury Neutrino Observatory (SNO) ceased operations in 2006, but plans are underway to upgrade the detector. The main difference between SNO and SNO+ will be the detecting material.

James Trefil, *a frequent contributor to* Astronomy, *is Clarence J. Robinson Professor of Physics at George Mason University.* **Wanda O'Brien-Trefil** *teaches English in the Montgomery County, Maryland, public schools.*



Super-Kamiokande consists of 11,146 light detectors called photomultiplier tubes (PMTs). The experiment began in 1996 and stopped in 2001 after roughly half of the PMTs imploded in a chain reaction. After about a year, technicians repaired the detector. Kamioka Observatory/ICRR (Institute for Cosmic Ray Research)/The University of Tokyo

The second problem is more subtle. When we "detect" a neutrino, we are actually seeing an atom do something — recoil or undergo a nuclear reaction — that we ascribe to the presence of a particle we can't see. The question then is: What else could cause the atom to do the same thing? For example, high-energy particles called cosmic rays constantly bombard us at Earth's surface. Sorting out which reactions cosmic rays cause and separating them from the reactions neutrinos cause is not easy. We call this the "background" problem.

Cleaning them out

Beginning in the 1960s, Ray Davis of the University of Pennsylvania carried out the first major attempt to solve these problems. Davis' neutrino target was a railroad tank car of tetrachloroethene — a dry-cleaning chemical and a good source of chlorine. (He would joke that if his experiment failed, he could always go into the cleaning business.)

Davis dealt with the background problem by placing his experiment a mile underground, in the Homestake Gold Mine in Lead, South Dakota. There the thick rock overburden shielded his apparatus. His goal was to look at neutrinos produced by nuclear fusion reactions in the Sun's core. In his tank car full of fluid, these solar neutrinos would convert about one atom of chlorine a day into an atom of argon. He had to find those lonely argon atoms in the sea of cleaning fluid. Compared with this, finding a needle in a haystack is child's play!

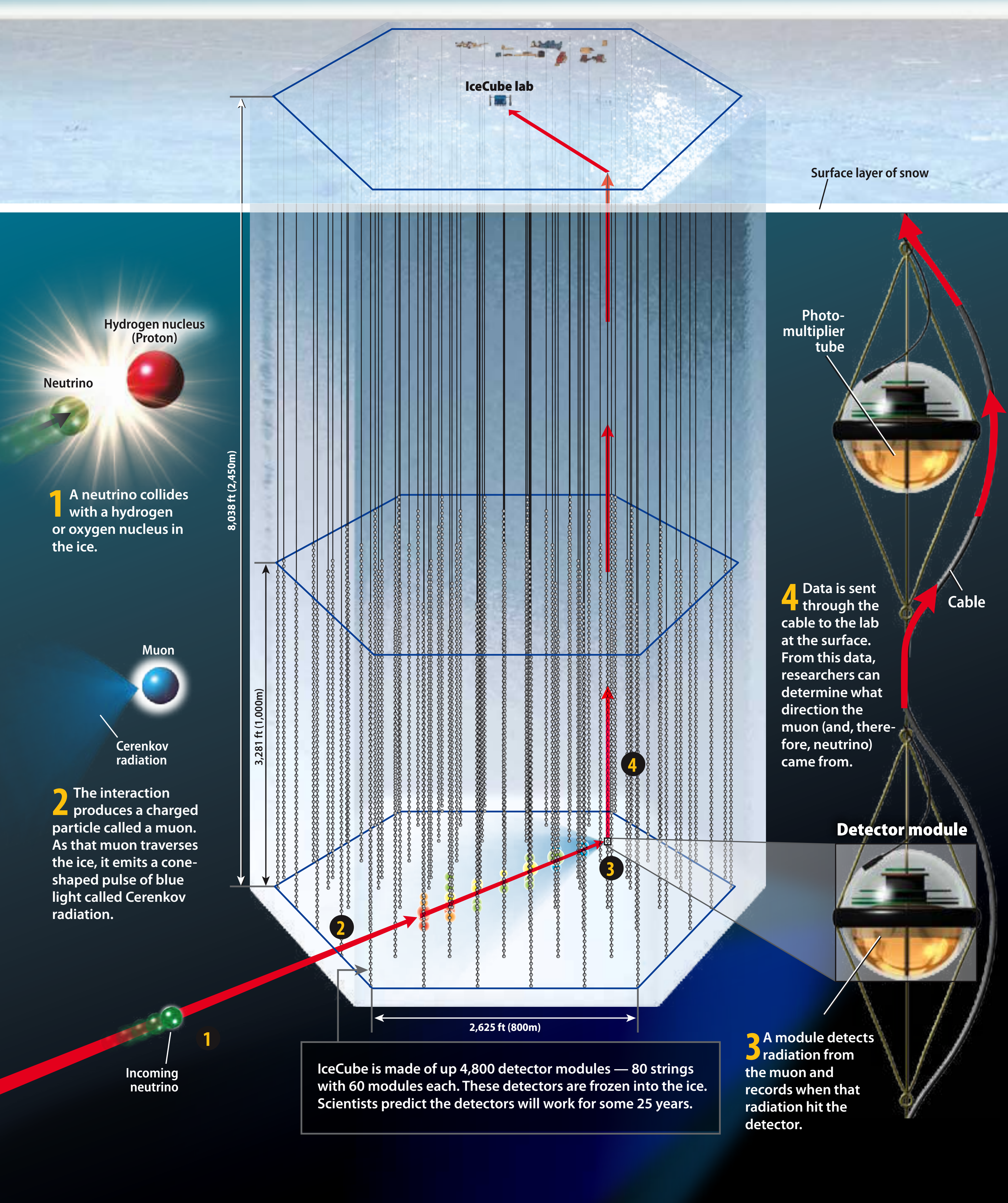
As often happens when scientists explore new territory, Davis' experiment produced results no one expected. He saw his solar neutrinos, all right, but in the process he discovered something important about the particles as well as about the Sun. Davis' experiment detected only about one-third of the expected number of neutrinos. Was his experimental technique wrong? Did physicists make incorrect calculations about how many neutrinos they should detect? Or maybe we didn't fully understand the physics. It turns out that neutrinos come in three distinct species, and these species can transform themselves, one into the other. This fact has since become a cornerstone of modern physics theories. (Davis received the 2002 Nobel Prize in physics for his work.)

Following Davis' success, physicists built a second generation of neutrino detectors. All involved massive targets in deep mines or tunnels in North America, Europe, or Japan. Many used a new detection strategy in which ultrapure water was the target.

A neutrino passing through the water can produce a charged particle during a nuclear reaction. In water that particle emits a cone-shaped pulse of bluish light — think of this as the optical equivalent of a sonic boom. Banks of instruments surrounding the water detect this so-called "Cerenkov radiation" (named for the Russian physicist Pavel Cerenkov). The strategy in these laboratories was simple: The

The IceCube Neutrino Observatory

The IceCube Neutrino Observatory, located at the Geographic South Pole, uses Earth as a filter to block unwanted particles (such as high-energy cosmic rays and incoming radiation).


IceCube lab
Surface layer of snow
8,038 ft (2,450m)
3,281 ft (1,000m)
2,625 ft (800m)
Hydrogen nucleus (Proton)
Neutrino
Muon
Cerenkov radiation
Incoming neutrino
Photo-multiplier tube
Cable
Detector module
1
2
3
4

1 A neutrino collides with a hydrogen or oxygen nucleus in the ice.

2 The interaction produces a charged particle called a muon. As that muon traverses the ice, it emits a cone-shaped pulse of blue light called Cerenkov radiation.

3 A module detects radiation from the muon and records when that radiation hit the detector.

4 Data is sent through the cable to the lab at the surface. From this data, researchers can determine what direction the muon (and, therefore, neutrino) came from.

IceCube is made of up 4,800 detector modules — 80 strings with 60 modules each. These detectors are frozen into the ice. Scientists predict the detectors will work for some 25 years.

Astronomy: Roen Kelly, after the IceCube Collaboration great mass of water would act both as a target with which the neutrinos would interact and the medium that allowed physicists to detect the aftereffects of that interaction. With these instruments and others like them, the neutrino window on the universe began to open.

Ice: nature's laboratory

But when it comes to looking for the rare neutrinos associated with extremely violent events, ultrapure water detectors, as massive as they are, are too small for the job. The detected particles associated with these events are so rare that scientists might have to wait decades for one of them to interact with an atom in a tank of water tens of meters on a side. What is needed is a detector with dimensions measured in kilometers rather than meters.

Enter IceCube.

Arguably the most spectacular astronomical instrument ever built, IceCube is 0.24 cubic mile (1 cubic kilometer) of instrumented ice located at the South Pole. In this detector, the ice takes the place of the ultrapure water in previous systems, acting both as the target and the medium that scientists will monitor for the presence of neutrino interactions.

So, why the South Pole? "We need a cubic kilometer of transparent target material to see the high-energy neutrinos we're looking for," says Spencer Klein of the Lawrence Berkeley National Laboratory and the University of California, one of the scientific leaders of IceCube. "We could never build a detector that big, so we have to look for one in nature. The South Pole sits on a layer of ice 2,800 meters [1.7 miles] thick. In addition, as remote as it is, airplanes fly regularly to South Pole Station, so getting equipment delivered isn't an issue."

The technique for building the instrument is simple to describe, if somewhat more difficult to carry out. Scientists use high-pressure heated water to drill holes into the ice — an 8,040-foot (2,450 meters) hole takes about 40 hours to complete. Researchers then lower a cable with a string of 60 detectors into the hole, and the ice freezes around it. When a neutrino triggers a reaction with an atom in the ice, the newly created particle produces flashes of light, which detector modules record. From this data, computers at the surface can reconstruct properties of each neutrino. They can, for example, determine its energy and the direction from which it came.

After drilling the 8,040-foot (2,450 meters) hole into antarctic ice, scientists lower a string of 60 modules into the hole. As of early 2009, 59 out of 80 of these strings had been deployed. Mark Krasberg/NSF

There was a mild panic when the first detector strings didn't function properly after researchers lowered them into the ice. It turned out that tiny bubbles of trapped air were scattering the light before it reached the detectors. Fortunately, scientists found that at depths greater than 4,590 feet (1,400m) the ice pressure is so high that the bubbles collapse and restore the clean signal researchers need. So the top of the array sits at 4,760 feet (1,450m) and extends 3,280 feet (1,000m) down.

As of the end of the 2008–2009 austral summer, researchers had installed 59 of the planned 80 instrument strings. Klein estimates that the entire instrument will be complete by January 2012. Even with only part of their instrument in place, scientists can start taking data.

"Most of what we see are atmospheric neutrinos," says Klein, referring to neutrinos created in Earth's atmosphere. Incoming cosmic rays and their collision products initiate nuclear reactions. These events outnumber interactions that incoming neutrinos induce by more than 500,000-to-1 — a major background problem. Consequently, IceCube scientists also look for a kind of event in which the initiating neutrino is moving up toward the surface. These neutrinos have penetrated Earth on their way to the detector, something no other kind of particle can do. In effect, the planet screens out unwanted background signals.

One amazing aspect of this setup, according to Klein, is that IceCube can detect events called extensive air showers taking place at the North Pole. In these events, a cosmic ray of extremely high energy enters the atmosphere above the North Pole, initiating a nuclear cascade that can produce a million downward-moving particles. Some of them will be neutrinos that travel through Earth before IceCube's instruments capture them.

Once IceCube is fully up and running, scientists expect it to record more than a million high-energy neutrino events during a period of about 10 years. This will give us a massive database for analyzing the most violent events in the universe, and it might also lead to new physics.

But the most important finding likely to come as we open the neutrino window is what comes when we open any new window — it's the thing we don't expect. ◑

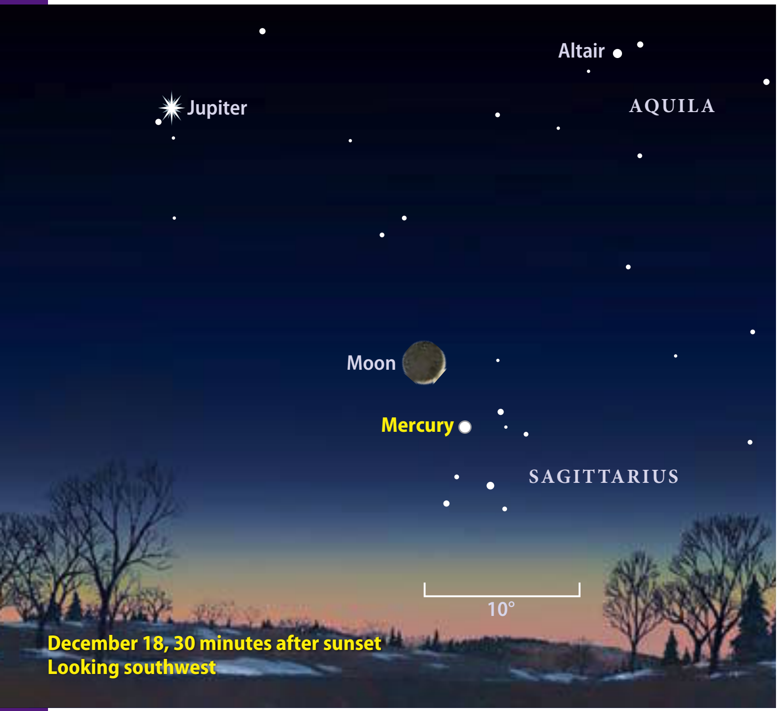
A+ **Learn about the detectors hunting neutrinos at www.Astronomy.com/toc.**

The Sky this Month

Martin Ratcliffe and Alister Ling describe the solar system's changing landscape as it appears in Earth's sky.

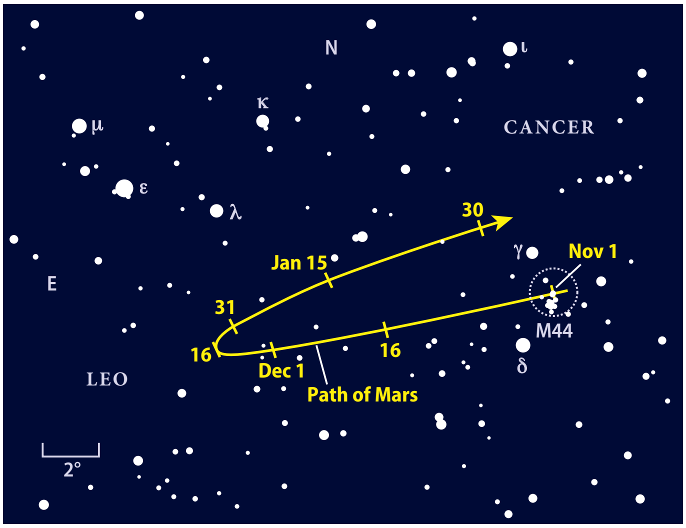
December 09

Mars set for prime time



December 18, 30 minutes after sunset
Looking southwest

Mercury shines brightly in the evening sky this month. The best day to find it is December 18, when it lies farthest from the Sun and just below a crescent Moon. *Astronomy*: Roen Kelly



Mars shifts direction against the background stars of Leo the Lion around mid-December. The start of this "retrograde loop" heralds the planet's opposition in late January. *Astronomy*: Roen Kelly

Jupiter and Mars draw the top headlines in December's evening sky. But while Jupiter is nearing the end of its current evening visibility, Mars is just beginning. Mercury joins the action right after sunset starting the second week of the month.

At the other end of the night, Saturn returns nicely in the morning sky. Its nearly edge-on rings are starting to widen slowly. To cap all this planetary excitement, two fine meteor showers and a partial eclipse of the Moon add to the festive season as 2009 draws to a close.

Mercury pops out of the Sun's glow during December's second week. If you have a clear and unobstructed southwestern horizon, the planet stands 5° high 30 minutes after sunset December 9. At magnitude –0.6, Mercury shines brightly enough to pierce the twilight glow.

The innermost planet climbs higher in the evening sky with each passing day until December 18, when it reaches greatest elongation from the Sun. Mercury then lies 20° east of our star and appears 8° high 30 minutes after sunset. That same night, a slender crescent Moon stands 6° to Mercury's upper left.

Take a few minutes every couple of nights to view Mercury through a telescope. You will see its disk grow larger while its phase dwindles. On December 10, the planet appears 6" across and more than three-quarters lit. By the 21st, the disk has grown to 7" in diameter while the illumination has shrunk to half-lit. Mercury fades rapidly and drops out of sight before the month ends.

Although Mercury has a nice apparition this month, it can't compare with **Jupiter**. The giant planet shines at magnitude –2.2 and appears brighter than any other point of light in the night sky. Look for it in the southwest as twilight deepens.

Although Jupiter now appears 25 percent smaller

— *Continued on page 41*

36 **Mercury in the evening** 👁 ⚯ 🔭
36 **Mars on the move** 👁 ⚯ 🔭
41 **Meteor watch** 👁
41 **Rising Moon** 🔭
42 **When to view the planets** 👁 ⚯ 🔭
42 **Io and Europa come together** 🔭
42 **Comet search** 🔭
43 **Locating asteroids** ⚯ 🔭
43 **A Full Moon in eclipse** 👁 ⚯ 🔭

👁 **Visible to the naked eye**
⚯ **Visible with binoculars**
🔭 **Visible with a telescope**

Astronomy magazine

Sky Guide 2010

By Martin Ratcliffe
and Richard Talcott

Up to 5 minutes of totality await observers during July's solar eclipse. Highlights of a total eclipse include jewel-like Baily's beads and reddish prominences. Tunç Tezel

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XVI **2011 Preview** Looking ahead to next year

Martin Ratcliffe *provides professional planetarium development for Sky-Skan Inc.* **Richard Talcott** *is a senior editor of* Astronomy *magazine.*

A supplement to *Astronomy* magazine

2009
Dec

S	M	T	W	T	F	S
		1	●	3	4	5
6	7	◐	9	10	11	12
13	14	15	○	17	18	19
20	21	22	23	◑	25	26
27	28	29	30	●		

6	The Moon passes 6° south of Mars, 10 P.M. EST	✓	✓	
10	The Moon passes 8° south of Saturn, 6 A.M. EST	✓	✓	
14	Geminid meteor shower peaks	✓		
18	The Moon passes 1.4° north of Mercury, 3 A.M. EST	✓	✓	
	Mercury is at greatest eastern elongation (20°), noon EST	✓	✓	✓
19	Jupiter passes 0.6° south of Neptune, midnight EST		✓	✓
21	The Moon passes 4° north of Jupiter, 10 A.M. EST	✓	✓	
	The Moon passes 4° north of Neptune, 10 A.M. EST		✓	
	Solstice (northern winter/southern summer begins), 1 P.M. EST	✓		
23	The Moon passes 6° north of Uranus, 9 P.M. EST		✓	
24	Pluto is in conjunction with the Sun, 1 P.M. EST			
31	Partial lunar eclipse, 2 P.M. EST	✓	✓	✓

Events that can be viewed with **the naked eye**

Events that can be viewed with **binoculars**

Events that can be viewed with a **telescope**

Jupiter's moons on parade

Jupiter's moons dance continuously, offering a different scene every night. Here, Europa lies to the planet's left, and its shadow hits the cloud tops next to Ganymede. Io lies well to Jupiter's right. Mike Salway

Jupiter and its four bright Galilean moons always look spectacular through a telescope. But once every 6 years or so, they do something truly amazing: The moons' orbits turn edge-on to the Sun. For observers on Earth, this alignment means the moons occasionally pass in front of one another or cast their shadows onto other moons. This month wraps up the latest such series of mutual events.

During December, 23 mutual events occur. All involve one moon passing in front of another, occulting it from view. During such events, the two moons appear to merge, and their combined light drops. Unfortunately, Jupiter now lies in the evening sky, so observers at any single location can see only a small fraction of the 23 total events.

Those in North America have two good viewing opportunities. On the evening of December 2, Io occults Europa. The event starts at 9:08 P.M. EST and lasts just 5 minutes. Because Io is bigger than Europa and covers most of the smaller moon, the pair's light dims by nearly half.

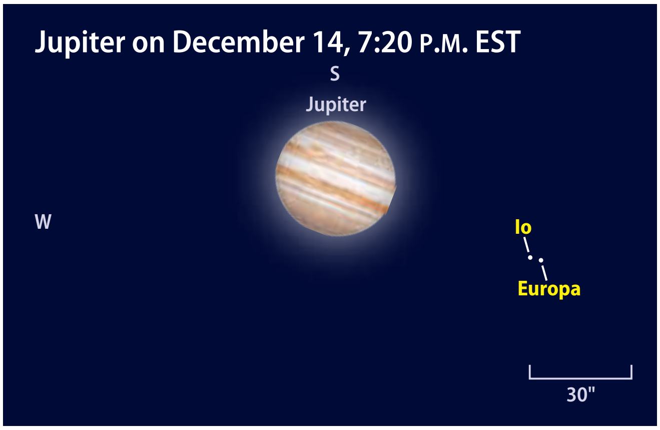
The second event involves the same two moons, but in this case Europa passes in front of Io. The occultation begins at 7:26 P.M. EST December 14 and lasts only 4 minutes. At maximum, Europa covers about half of Io, so the total light drops only 23 percent.

If clouds interfere on both the 2nd and 14th, you might want to shoot for a third event. Starting at 7:49 P.M. EST December 12, Ganymede occults Europa. Because Ganymede is Jupiter's biggest and brightest moon, the overall light drops just 3 percent, so this event won't appear as spectacular as the other two.

The best occultation for European observers comes December 7. Europa then occults Io, with first contact coming at 22h05m Universal Time. The pair's light will drop by one-third and then recover to full intensity, all within 4 minutes.

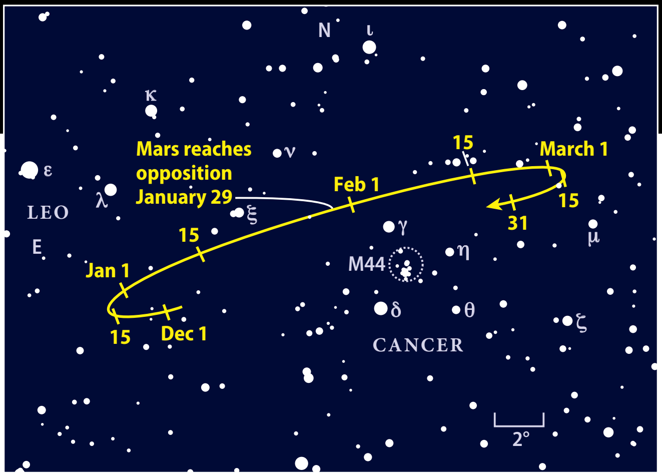
With any of these events, set up your telescope early in the evening so it has time to cool down to the ambient air temperature. This will help you get steady views of Jupiter and its moons. You'll want to crank up the magnification as much as the seeing allows. Only under exceptional conditions will you be able to see the moons' disks. (Even giant Ganymede spans only a bit more than 1".)

Don't pass up these final chances to view the jovian moons' mutual events. You won't get another opportunity until the moons' orbits turn edge-on again in 2015.



Io and Europa seem to merge December 14. This view shows those jovian moons a few minutes before Europa occults Io. *Astronomy*: Theo Cobb

Mars shines at its best



Astronomy: Theo Cobb

Mars shines brightly throughout these long winter nights. It forms a nice pair with the Beehive star cluster (M44) in early February.

This year gets off to a smashing start with Mars gleaming brightly all night long. It reaches opposition and peak visibility January 29. The planet's orange glow seems to warm these cold midwinter nights. You can find Mars against the faint background of Cancer the Crab, midway between the 1st-magnitude stars Pollux (in Gemini the Twins) and Regulus (in Leo the Lion).

Mars shines at magnitude −1.3 at opposition. It currently has only two rivals: brilliant Jupiter low in the southwest after sunset and Sirius well to the south of Mars. Although the Red Planet appears best at opposition, it remains a fine sight for several months.

Mars reaches opposition approximately every 2 years, but all oppositions are not created equal. Sometimes they occur when Mars lies close to the Sun; at other times, the planet is relatively distant. The last close opposition occurred in August 2003. Mars then shone at magnitude −2.9 and reached an apparent diameter of 25".

This year's opposition doesn't fare so well. Mars shines only one-quarter as brightly as it did in 2003, and with a diameter of 14", it appears barely half as big.

Still, Mars will show quite a bit of detail through 6-inch and larger telescopes. The best times to view are when Mars' diameter exceeds 10". This will be the case from December 2009 until the end of March.

Wait until Mars climbs high in the sky, around local midnight, when its light passes through less of Earth's turbulent atmosphere. Observers do have one significant advantage this year: Mars lies well north of the celestial equator, so it climbs high in the sky for observers in the Northern Hemisphere.

Mars also treats binocular observers in February and April. As it heads first west and then east through Cancer, the Red Planet passes north of the lovely Beehive star cluster (M44).

At its first pass of the year, in early February, Mars lies 3° north of the cluster. The planet then wanders closer to Gemini before turning back toward central Cancer. In mid-April, Mars passes 1° north of the Beehive. The planet then appears dimmer, at magnitude 0.5, but still easily outshines the cluster's stars.

The Red Planet looms big and bright when it comes closest to Earth in late January. NASA/ESA/ Hubble Heritage Team (STScI/AURA)

2010 Jan

S	M	T	W	T	F	S
					1	2
3	4	5	6	◐	8	9
10	11	12	13	14	○	16
17	18	19	20	21	22	◑
24	25	26	27	28	29	●
31						

3	The Moon passes 7° south of Mars, 7 A.M. EST
	Quadrantid meteor shower peaks
4	Mercury is in inferior conjunction, 2 P.M. EST
6	The Moon passes 8° south of Saturn, 2 P.M. EST
11	The Moon passes 1.1° north of Antares, 8 A.M. EST
	Venus is in superior conjunction, 4 P.M. EST
13	The Moon passes 5° south of Mercury, 11 A.M. EST
15	Annular solar eclipse, 2 A.M. EST
17	The Moon passes 4° north of Neptune, 6 P.M. EST
18	The Moon passes 5° north of Jupiter, 5 A.M. EST
20	The Moon passes 6° north of Uranus, 6 A.M. EST
26	Mercury is at greatest western elongation (25°), midnight EST
29	Mars is at opposition, 3 P.M. EST
30	The Moon passes 7° south of Mars, 3 A.M. EST

Feb 2010

S	M	T	W	T	F	S
	1	2	3	4	◑	6
7	8	9	10	11	12	●
14	15	16	17	18	19	20
◐	22	23	24	25	26	27
○						

2	The Moon passes 8° south of Saturn, 9 P.M. EST
7	The Moon passes 1.1° north of Antares, 2 P.M. EST
12	The Moon passes 2° north of Mercury, 1 A.M. EST
14	Neptune is in conjunction with the Sun, 6 P.M. EST
16	The Moon passes 6° north of Uranus, 2 P.M. EST
18	Asteroid Vesta is at opposition, 1 A.M. EST
25	The Moon passes 5° south of Mars, midnight EST
28	Jupiter is in conjunction with the Sun, 6 A.M. EST

Vesta reaches a dramatic peak

This month provides a perfect opportunity to track down an asteroid. Vesta brightens to magnitude 6.1 when it reaches opposition February 17/18. The asteroid will be visible to naked eyes from a dark site and an easy target through binoculars from the suburbs.

Vesta's location against the conspicuous background of Leo the Lion makes the task even easier. In late January, Vesta lies due north of 5th-magnitude 46 Leonis, which itself lies 6° east-northeast of 1st-magnitude Regulus. The asteroid's nightly motion then carries it northwest toward 2nd-magnitude Algieba, a fine double star also known as Gamma (γ) Leonis.

On February 16/17, Vesta passes between Algieba and its 5th-magnitude neighbor, 40 Leonis. At opposition the next night, Vesta lies less than 1 Moon-width west of Algieba. Binoculars or a small telescope at low power will yield the best views of the asteroid and nearby stars.

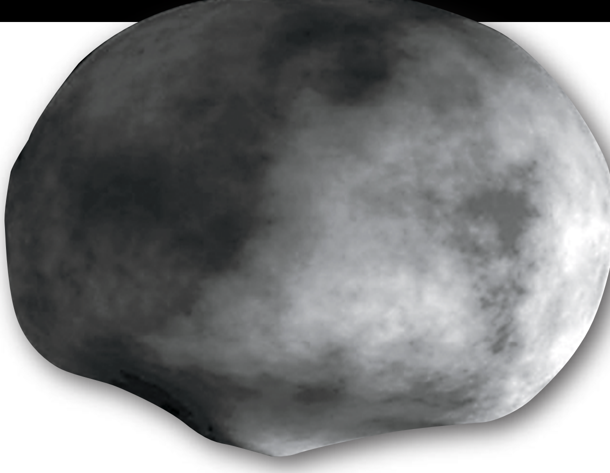
After opposition, Vesta continues northwest toward 3rd-magnitude Epsilon (ε) Leonis, the star at the tip of Leo's Sickle asterism. The asteroid arrives in late March and remains within 2° of this star for a couple of weeks. Although Vesta then glows at 7th magnitude, binoculars still provide an excellent view.

German astronomer Heinrich Olbers discovered Vesta March 29, 1807. It was his second asteroid find — he spotted Pallas 5 years earlier.

Astronomers consider Vesta to be a Rosetta stone to the formation of the solar system. Detailed spectroscopic observations combined with high-resolution images from the Hubble Space Telescope reveal the asteroid's basaltic surface and at least one huge crater near its south pole. Most researchers think Vesta is differentiated, meaning it was molten early in the solar system's history. That allowed heavier materials to sink to the core before the object cooled and solidified.

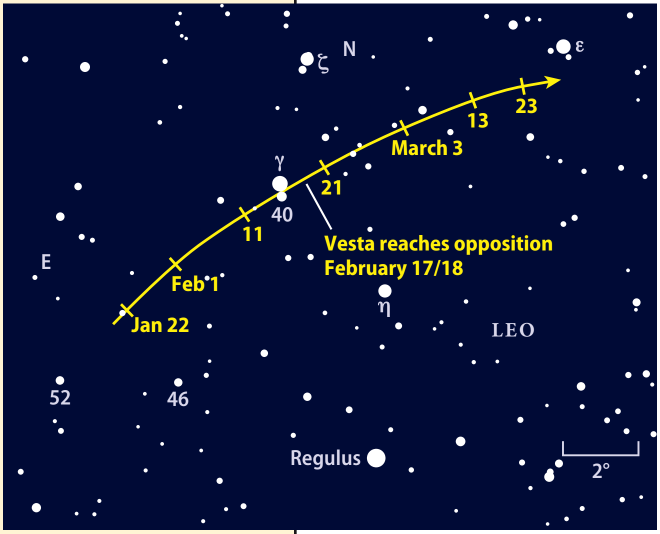
Both Vesta and the largest asteroid, Ceres, apparently survived intact despite the chaotic conditions within the asteroid belt. Most other asteroids seem to be collisional fragments.

To get a better idea of the solar system's early days, NASA launched a spacecraft toward Vesta and Ceres in 2007. Dawn will arrive at Vesta in August 2011. Using its ion drive, previously demonstrated on the Deep Space 1 mission, Dawn will go into orbit around Vesta and study the asteroid in detail. It will remain there until May 2012, when it will fire its engines once more and head off to Ceres. Dawn will reach the biggest asteroid and begin orbiting it in February 2015.



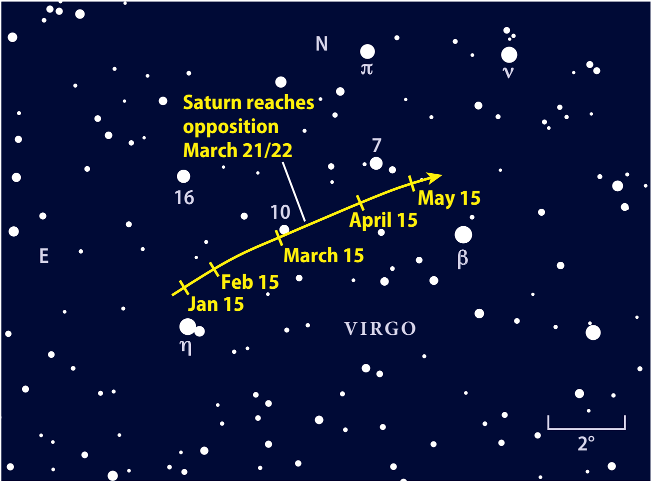
Ben Zellner (Georgia Southern University)/Peter Thomas (Cornell University)/NASA

A huge impact rocked Vesta eons ago, forming a giant crater and central mountain peak near the asteroid's south pole (bottom).



Track Vesta — the sky's brightest asteroid — with binoculars as it travels through Leo north of 1st-magnitude Regulus. *Astronomy:* Theo Cobb

Saturn opens its rings



Saturn slides through western Virgo this winter and spring. Gleaming at 1st magnitude, the planet easily outshines its neighboring stars and ranks among the brightest objects in the sky. *Astronomy*: Theo Cobb

The rings are back! Saturn will be a spectacular object nearly all year, but never more so than when it reaches opposition March 21. The rings open nicely as Saturn moves along its orbit. You can follow their grand and gradual appearance throughout 2010.

At the beginning of the year, Saturn rises at midnight among the background stars of western Virgo. It then lies just 1° north of the 4th-magnitude star Eta (η) Virginis. Its shining orb glows at magnitude 0.9, while the rings span 40" and tilt 5° to our line of sight.

Saturn rises a few minutes earlier each night. By the time it reaches opposition, the ringed planet rises at sunset and stands above the eastern horizon as twilight begins to fade. At magnitude 0.5, it outshines all the background stars in Virgo the Maiden. Saturn's westward motion against this backdrop brings it roughly halfway between Eta and 4th-magnitude Beta (β) Virginis at opposition.

Opposition marks the planet's closest approach to Earth during 2010. Despite Saturn's large globe — its equator spans 74,900 miles — it appears tiny due to its vast distance. Saturn's angular diameter peaks at 19.5". Even a small telescope shows the disk's obvious flattening. The planet's gaseous nature and rapid rotation cause the polar diameter to be 10 percent smaller than its equatorial girth. At opposition, Saturn measures 17.6" from pole to pole.

The rings also max out at opposition, spanning 44.4", although their tilt has narrowed to 3° because Earth briefly comes closer to Saturn's equatorial plane. Take some time to look at Saturn's atmosphere. Although not as dramatic as the high-contrast features in Jupiter's atmosphere, Saturn shows some dark banding, and white spots occasionally pop out.

While you have a telescope focused on Saturn, look for its brighter moons. Any scope will show you 8th-magnitude Titan, which conveniently lies due north of the planet at opposition. Tenth-magnitude Tethys, Dione, and Rhea show up best in 6-inch or larger scopes. Also keep an eye out for Iapetus, which glows at 10th magnitude when far west of Saturn and at 12th magnitude when far east.

After opposition, Saturn becomes better placed for evening viewing. It passes within 2° of Beta Virginis in late May, but then starts moving eastward and away from this star.

Saturn remains visible until early September, when it disappears into the Sun's glow. It returns to view in the morning sky by late October. By then, the rings tilt 8° to our line of sight; they open to 10° by year's end. You can expect spectacular views of both the A and B rings, along with the dark Cassini Division that separates the two.

NASA/ESA/Hubble Heritage Team (STScI/AURA)

Saturn's rings return to view this year. The spectacular rings tilted edge-on to Earth for much of 2009, but they will open up nicely toward the end of 2010.

2010 March

S	M	T	W	T	F	S
	1	2	3	4	5	6
◑	8	9	10	11	12	13
14	●	16	17	18	19	20
21	22	◐	24	25	26	27
28	○	30	31			

2	The Moon passes 8° south of Saturn, 5 A.M. EST
13	The Moon passes 4° north of Neptune, 11 A.M. EST
14	Mercury is in superior conjunction, 9 A.M. EDT
17	Uranus is in conjunction with the Sun, 3 A.M. EDT
	The Moon passes 7° north of Venus, 8 A.M. EDT
20	Equinox (northern spring/southern autumn begins), 2 P.M. EDT
21	Saturn is at opposition, 9 P.M. EDT
25	The Moon passes 5° south of Mars, 10 A.M. EDT
29	The Moon passes 8° south of Saturn, 2 p.m. EDT

2010 April

S	M	T	W	T	F	S
				1	2	3
4	◐	6	7	8	9	10
11	12	13	○	15	16	17
18	19	20	◑	22	23	24
25	26	27	●	29	30	

8	Mercury is at greatest eastern elongation (19°), 7 P.M. EDT
9	The Moon passes 4° north of Neptune, 9 P.M. EDT
11	The Moon passes 6° north of Jupiter, 6 P.M. EDT
12	The Moon passes 6° north of Uranus, 10 A.M. EDT
15	The Moon passes 1.5° north of Mercury, 7 P.M. EDT
16	The Moon passes 4° north of Venus, 9 A.M. EDT
22	The Moon passes 5° south of Mars, 5 A.M. EDT
	Lyrid meteor shower peaks
25	The Moon passes 8° south of Saturn, 8 P.M. EDT
28	Mercury is in inferior conjunction, 1 P.M. EDT

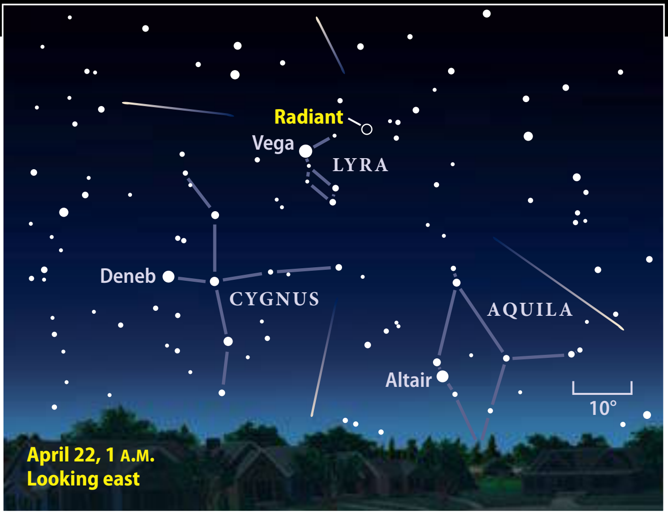
For more on these and other sky events throughout the year, go to Astronomy.com.

A year of flashing meteors

It doesn't get much better than standing underneath the canopy of stars, watching debris from old comets streak like high-speed fireflies across the sky. Shooting stars, meteors, tears of the gods — call them what you will — each one elicits a gasp from anyone watching.

The best opportunity for meteor viewing during the first half of 2010 comes with April's Lyrid meteor shower. At its peak before dawn April 22, observers under clear, dark skies can expect to see up to 20 meteors per hour. The Moon is then at first quarter phase, so it sets before the prime viewing hours after midnight.

Meteors arise when tiny bits of debris collide with Earth's atmosphere. Sometimes this happens randomly; at other times, they arrive in bunches. The bunches come when Earth crosses the orbital path of a comet that has made many trips through the inner solar system. The Sun heats the comet's icy nucleus, and the tiny dust grains liberated eventually spread out along the orbit.



Lyrid meteors will streak across the sky around April 22. A First Quarter Moon will compete with the meteors during the evening hours but will set shortly after midnight. *Astronomy*: Theo Cobb

Don't think of the meteors as hitting Earth; it's the other way around. The best time to view a meteor shower is after midnight when you're on the side of Earth facing forward in its orbit. It's akin to driving through a snowstorm — lots more snowflakes hit the front windshield than the rear one.

The best views come under a dark sky. The veil of light pollution that surrounds cities will drown out fainter meteors, reducing the number you see. For the same reason, the best showers in any year are those that occur without a bright Moon in the morning sky.

So where does that leave us for 2010? Of the three major showers that occur in the first half of the year, only the Lyrids escape a bright Moon. January's Quadrantid shower suffers from a waning gibbous Moon, while May's Eta Aquarid shower coincides with a Last Quarter Moon. That makes the Lyrid shower this year's winner.

The second half of 2010 should provide more thrills. August's Perseid shower peaks near New Moon, so it should be the show of the year (see August for details). And December's Geminid shower should be fine once the First Quarter Moon sets shortly after midnight. Both showers can produce up to 100 meteors per hour under a clear sky. The Moon creates significantly bigger problems for October's Orionids and November's Leonids.

Meteor showers in 2010

Name	Peak date	Moon's phase	Prospects
Quadrantids	Jan. 3	Waning gibbous	Poor
Lyrids	April 22	First Quarter	Good
Eta Aquarids	May 6	Last Quarter	Fair
Perseids	Aug. 12	Waxing crescent	Excellent
Orionids	Oct. 21	Waxing gibbous	Poor
Leonids	Nov. 17	Waxing gibbous	Fair
Geminids	Dec. 14	First Quarter	Excellent

Mercury on display

Broad and deep craters highlight this view of Mercury, taken by NASA's MESSENGER spacecraft. Unfortunately, the innermost planet appears small and featureless from Earth. NASA/JHUAPL/CIW

Even glimpsing the solar system's innermost planet can be troublesome at times. At others, Mercury's a cinch to see. One of your better chances arrives during morning twilight in late May. The peak of this apparition comes at greatest western elongation May 25/26.

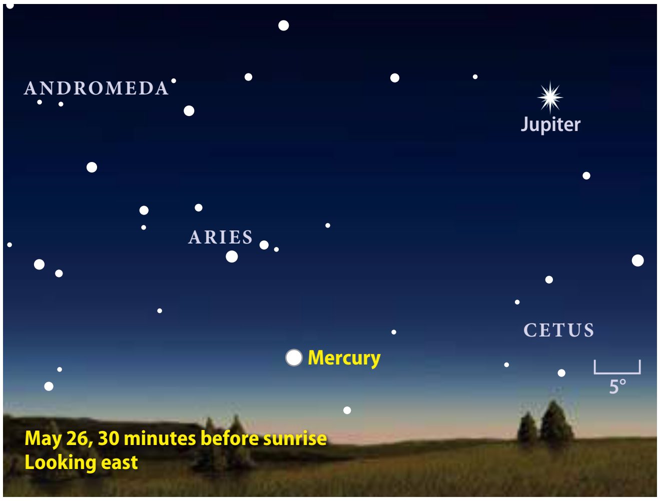
For observers at 30° north latitude, Mercury appears 8° above the eastern horizon 30 minutes before sunrise. (Eight degrees is about the angle made by a closed fist when held at arm's length.) If you live farther north, Mercury lies closer to the horizon. But for those in more southerly locales, Mercury rises well before twilight begins.

Seeing Mercury depends on several factors. The innermost planet never strays far from the Sun, so it appears only low in the eastern sky before dawn or in the west after sunset. It climbs highest around the times of greatest elongation, but not all elongations are equally favorable. Your local environment also plays a role — hills, trees, or buildings can block a clear view.

For southern observers, late May offers the best morning view this year. But for those in much of the Northern Hemisphere, late September will see the planet climb higher. At greatest elongation September 19, Mercury appears 11° high 30 minutes before sunrise.

For those who don't like getting up before dawn, the evening sky also provides some good viewing opportunities. From the Northern Hemisphere, Mercury climbs highest around its April 8 greatest eastern elongation. Look for it 13° high in the west a half-hour after the Sun sets. Southern Hemisphere observers should target the greatest elongation August 6/7.

If you have trouble spotting Mercury with naked eyes, binoculars will bring it out of the twilight. For those with telescopes, the planet provides a constantly changing sight. Throughout an evening apparition, Mercury's disk grows larger and its phase dwindles. (It appears half-lit around the time of greatest elongation.) The show plays out in reverse during morning apparitions.



Mercury shines low in the morning sky during late May. Look for a bright dot piercing the twilight about 30 minutes before sunrise. *Astronomy*: Theo Cobb

2010 May

S	M	T	W	T	F	S
						1
2	3	4	5	◐	7	8
9	10	11	12	○	14	15
16	17	18	19	◑	21	22
23	24	25	26	●	28	29
30	31					

3	Asteroid Pallas is at opposition, midnight EDT	👓 🔭
	Venus passes 6° north of Aldebaran, midnight EDT	👁 👓
6	Eta Aquarid meteor shower peaks	👁
7	The Moon passes 4° north of Neptune, 6 A.M. EDT	👓
9	The Moon passes 7° north of Jupiter, 2 P.M. EDT	👁 👓
	The Moon passes 6° north of Uranus, 9 P.M. EDT	👓
12	The Moon passes 8° north of Mercury, 1 P.M. EDT	👁 👓
16	The Moon passes 0.08° north of Venus, 6 A.M. EDT	👁 👓 🔭
20	The Moon passes 5° south of Mars, 8 A.M. EDT	👁 👓
23	The Moon passes 8° south of Saturn, 1 A.M. EDT	👁 👓
25	Mercury is at greatest western elongation (25°), 10 P.M. EDT	👁 👓 🔭

2010
June

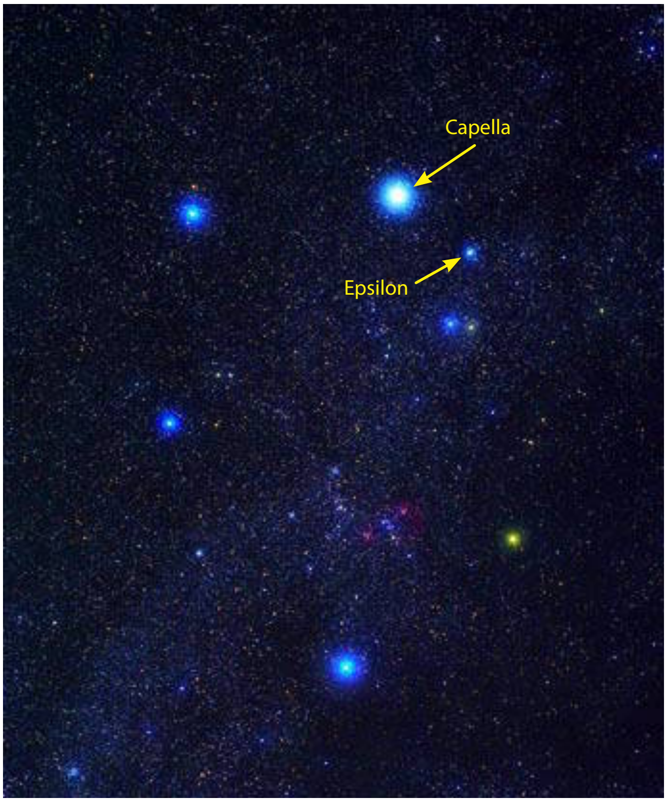
S	M	T	W	T	F	S
		1	2	3	◐	5
6	7	8	9	10	11	○
13	14	15	16	17	18	◑
20	21	22	23	24	25	●
27	28	29	30			

3	The Moon passes 5° north of Neptune, 2 P.M. EDT		∞	
6	The Moon passes 7° north of Jupiter, 7 A.M. EDT	👁	∞	
	The Moon passes 6° north of Uranus, 7 A.M. EDT		∞	
	Mars passes 0.9° north of Regulus, 11 A.M. EDT	👁	∞	🔭
	Jupiter passes 0.5° south of Uranus, 3 P.M. EDT		∞	🔭
9	Venus passes 5° south of Pollux, 6 A.M. EDT	👁	∞	
10	The Moon passes 5° north of Mercury, 11 P.M. EDT	👁	∞	
15	The Moon passes 4° south of Venus, 3 A.M. EDT	👁	∞	
	Mercury passes 5° north of Aldebaran, 10 P.M. EDT	👁	∞	
17	The Moon passes 6° south of Mars, 3 P.M. EDT	👁	∞	
18	Asteroid Ceres is at opposition, 6 P.M. EDT		∞	🔭
19	The Moon passes 8° south of Saturn, 7 A.M. EDT	👁	∞	
21	Solstice (northern summer/southern winter begins), 7 A.M. EDT	👁		
25	Pluto is at opposition, 3 P.M. EDT			🔭
26	Partial lunar eclipse, 8 A.M. EDT	👁	∞	🔭
30	The Moon passes 5° north of Neptune, 9 P.M. EDT		∞	

The sky's weirdest star

Most of the time, the star Epsilon (ε) Aurigae shines steadily at magnitude 3.0. Yet once every 27 years, it fades by more than half, to magnitude 3.8. The latest dimming started last summer, and this year the star should reach its minimum brightness.

It's a snap to find Epsilon Aurigae. It lies just southwest of Capella, the brightest star in the constellation Auriga the Charioteer and the sixth-brightest star in the entire night sky. In January, Auriga passes overhead around 9 P.M. It continues in the evening sky through spring. During the summer months, it appears low in the northeast before twilight, but rises 2 hours earlier each month. It becomes prominent after midnight by autumn.



Watch Epsilon (ε) Aurigae dim this year as it reaches the depths of its months-long eclipse. You can find Epsilon slightly southwest of brilliant Capella. Bill and Sally Fletcher

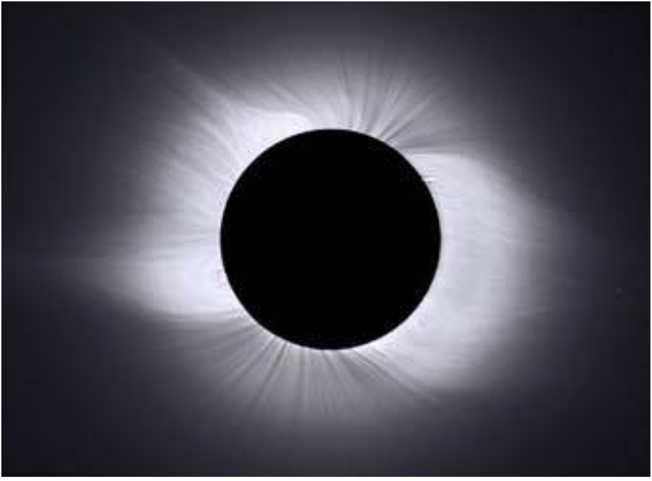
What's going on with this star? As early as the 19th century, astronomers realized that some sort of dark object was causing the dimming. Epsilon is an eclipsing binary, but of a type never seen before. Normal eclipsing binaries consist of two stars orbiting each other. But with Epsilon, no second star has ever been observed. Even more intriguing, minimum light lasts 2 years, which suggests that the eclipsing object must be elongated. But if it's a disk of dark material, as many scientists suspect, it must be partially transparent.

The previous eclipse lasted from 1982 to 1984. Astronomers predict the next one should begin in August 2009, with mideclipse coming in August 2010 and the end scheduled for March 2011. But Epsilon has thrown astronomers for a loop before, and there's no guarantee on these dates. That's one reason both professional and amateur observers around the world will monitor the star closely.

Of particular interest is the chance that Epsilon will brighten around mideclipse, as it has in the past. Many researchers think a hole in the center of the dark disk causes this brightening. Astronomer Robert Stencel, who is leading the Epsilon observing campaign, believes the first sign of brightening could occur in May 2010. Unfortunately, Auriga then lies low in the northwest after sunset, which will make observing the star more difficult.

Watching Epsilon fade and brighten will be exciting in its own right. But if you'd like to help astronomers unravel this stellar enigma, consider joining with the American Association of Variable Star Observers. You can get the details at its web site (aavso.org).

Totality's long return


Anthony Ayiomamitis

The Sun's corona takes center stage during a total solar eclipse. At other times, the Sun's glare obliterates this tenuous outer atmosphere.

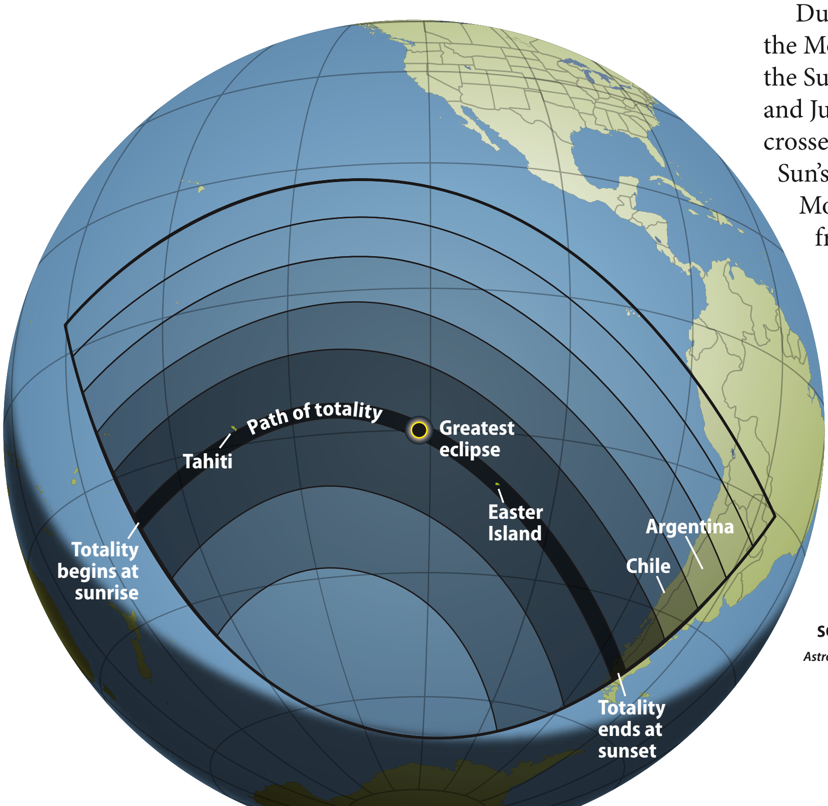
Mark July 11 on your calendar. On that date, the Moon will pass directly in front of the Sun and block it from view. If you're one of the lucky ones to stand in the path of totality, you'll be mesmerized by the Sun's gauzy corona and all the other features of a total solar eclipse.

Most of totality's track lies in the South Pacific Ocean. The path does cross two islands: Mangaia (the main island of the Cook Islands) and Easter Island. Observers on Mangaia will see about 3 minutes of totality, while those on Easter Island will experience more than 4 minutes. The path also makes landfall in southern Chile and ends in Argentina, where viewers will see the eclipsed Sun as its sets in the west. Maximum eclipse occurs over the open ocean far from land, where totality lasts 5 minutes and 20 seconds.

Clouds often rule over Pacific islands, so land-based expeditions could be hit or miss with the weather, much like they were in China in July 2009. Eclipse-chasers might be better off if they stay mobile — a great excuse to take a cruise.

The year's other solar eclipse occurs January 15. This one is annular, so at maximum a ring of sunlight remains visible around the Moon. The path starts at sunrise in central Africa, then crosses the Maldives, southern India, Sri Lanka, and Burma, and ends at sunset in China. At maximum, the ring of sunlight will last longer than 11 minutes.

During any solar eclipse, the Moon passes in front of the Sun. On both January 15 and July 11, the Moon crosses the center of the Sun's disk. In January, the Moon lies relatively far from Earth and can't block all of the Sun. In July, the Moon comes closer and completely hides the Sun's disk.



The path of totality July 11 covers a narrow strip of the South Pacific, passing near Tahiti and over Easter Island before ending in southern South America.

Astronomy: Roen Kelly

July 2010

S	M	T	W	T	F	S
				1	2	3
◑	5	6	7	8	9	10
●	12	13	14	15	16	17
◐	19	20	21	22	23	24
○	26	27	28	29	30	31

3	The Moon passes 7° north of Uranus, 4 P.M. EDT	∞
	The Moon passes 7° north of Jupiter, 9 P.M. EDT	👁 ∞
8	Asteroid Juno is in conjunction with the Sun, midnight EDT	
9	Venus passes 1.1° north of Regulus, 11 P.M. EDT	👁 ∞
11	Total solar eclipse, 4 P.M. EDT	👁 ∞ 🔭
12	The Moon passes 4° south of Mercury, 9 P.M. EDT	👁 ∞
14	The Moon passes 6° south of Venus, 9 P.M. EDT	👁 ∞
16	The Moon passes 6° south of Mars, 1 A.M. EDT	👁 ∞
	The Moon passes 8° south of Saturn, 3 P.M. EDT	👁 ∞
27	Mercury passes 0.3° south of Regulus, 7 P.M. EDT	👁 ∞ 🔭
28	The Moon passes 5° north of Neptune, 3 A.M. EDT	∞
30	The Moon passes 6° north of Uranus, 11 P.M. EDT	∞
31	The Moon passes 7° north of Jupiter, 5 A.M. EDT	👁 ∞

2010
Aug

S	M	T	W	T	F	S
1	2	◐	4	5	6	7
8	○	10	11	12	13	14
15	◑	17	18	19	20	21
22	23	●	25	26	27	28
29	30	31				

1 Mars passes 1.9° south of Saturn, 4 P.M. EDT

6 Mercury is at greatest eastern elongation (27°), 9 P.M. EDT

9 Venus passes 3° south of Saturn, 10 P.M. EDT

11 The Moon passes 2° south of Mercury, 10 P.M. EDT

12 Perseid meteor shower peaks

13 The Moon passes 8° south of Saturn, 3 A.M. EDT

The Moon passes 5° south of Venus, 8 A.M. EDT

The Moon passes 6° south of Mars, 1 P.M. EDT

19 Venus is at greatest eastern elongation (46°), midnight EDT

20 Neptune is at opposition, 6 A.M. EDT

23 Venus passes 2° south of Mars, 5 P.M. EDT

24 The Moon passes 5° north of Neptune, 8 A.M. EDT

27 The Moon passes 6° north of Uranus, 3 A.M. EDT

The Moon passes 7° north of Jupiter, 8 A.M. EDT

Perseids stand out in 2010

A Perseid meteor streaks across the summer sky in this view taken near the peak of the 2007 shower. Eddie Pavlu

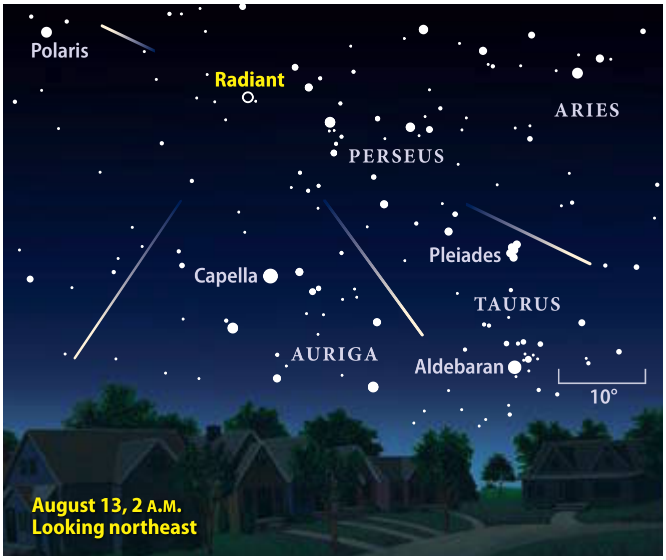
Without a doubt, the Perseid meteor shower ranks as the most popular annual shower. Not only does it typically produce lots of meteors, but it also occurs during warm summer weather when lots of people are on vacation. This year promises to be among the Perseids' best because it peaks the night of August 12/13 — just 3 days after New Moon. With no Moon in the sky, observers at dark sites could see up to 100 meteors per hour.

The Perseid shower lasts from July 17 to August 24. Activity starts slow, rises sharply toward maximum, and then slowly tails off. If you view the shower a night before or after its maximum, you'll likely see only one-quarter to one-half as many meteors. The best views come during the early morning hours when the radiant climbs highest in the sky.

Astronomers predict the Perseids' maximum to come in the late afternoon to early evening of the 12th for North American observers. (The timing works out better in Europe and Africa, where the peak comes after midnight.) Still, most people with clear skies viewing from a dark site should see an average of one meteor per minute (60 per hour). That number could climb to near 100 meteors per hour shortly before twilight begins.

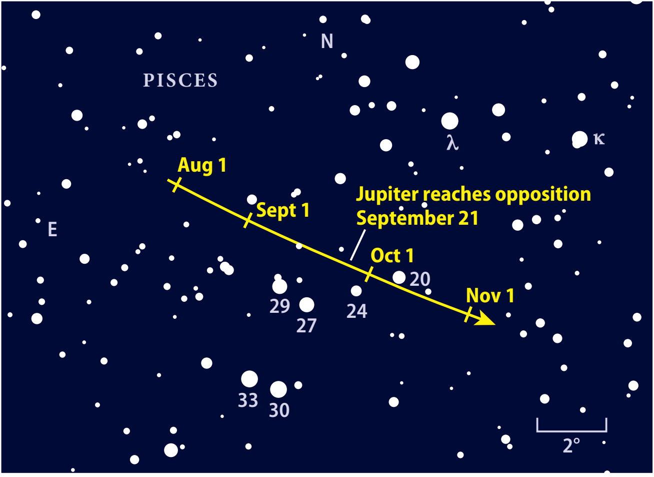
The Milky Way stretches across the middle of the sky during the shower's peak, arching overhead through Cygnus. This is a favorite region for spotting the swift bluish meteors. Many Perseids leave a persistent train, a glow left over as the small dust particles burn up in Earth's atmosphere.

The Perseids get their name from the constellation Perseus, the home of their radiant. All Perseid meteors appear to originate from this area. This is purely an effect of perspective — the meteors fly along parallel paths, but our location on Earth creates the illusion of diverging trails. The meteors derive from dusty debris ejected over the eons by Comet 109P/Swift-Tuttle. Every August, Earth slams into this thick debris trail, giving rise to the meteor shower.



The best meteor shower of 2010 should be the Perseids, whose peak nearly coincides with New Moon. Under a dark sky, observers can expect to see up to 100 meteors per hour. *Astronomy*: Theo Cobb

Jupiter shines big and bright



Brilliant Jupiter treks through the dim background of Pisces this summer and fall. The giant planet shines at magnitude –2.9 at its September peak. *Astronomy*: Theo Cobb

Just 2 years ago, Jupiter reached opposition among the background stars of Sagittarius. There, at the southern end of its 12-year orbit around the Sun, it never rose high above the horizon for northern observers. This year things are different. Jupiter reaches opposition and peak visibility September 21 in Pisces. It then stands more than halfway to the zenith at local midnight.

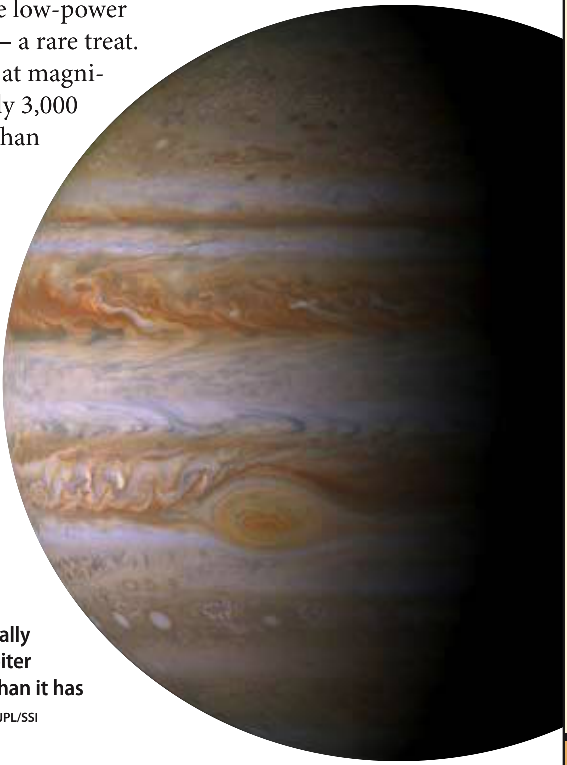
This healthy altitude means observers will see the giant planet through less of Earth's turbulent atmosphere — thus yielding sharper telescopic views — than at any time since 2005. But that's not all. Jupiter also lies closer to Earth at this opposition than it has since 1999. So, Jupiter shines brighter (at magnitude –2.9) and appears larger (49.9" across) than it has this century.

With Jupiter big and bright, take time to observe it through a telescope. Even a small instrument reveals two parallel dark belts, one on either side of a brighter equatorial zone. In moments of good seeing, several more belts and zones come into view. Also search for smaller features, including the Great Red Spot.

In addition, look at Jupiter's four bright moons. Italian scientist Galileo first glimpsed Io, Europa, Ganymede, and Callisto 400 years ago this January. Your small telescope will deliver a clearer view than Galileo's crude instrument.

Jupiter isn't the only planet plying Pisces. Uranus reaches opposition the same day as Jupiter. The two giant planets then lie less than 1° apart. You can see both within a single low-power field of view — a rare treat. Uranus glows at magnitude 5.7, nearly 3,000 times fainter than Jupiter.

The two remain near each other all year, but they come particularly close three times. On June 6, Jupiter passes 0.5° south of Uranus. The two meet again September 22, this time with a gap of 0.9°. The final meeting comes January 2, 2011, when Jupiter lies 0.6° south of its neighbor.



Jupiter's colorful cloud bands always look impressive through small telescopes. The view this year should be especially nice because Jupiter appears bigger than it has in a decade. NASA/JPL/SSI

2010 Sept

S	M	T	W	T	F	S
			◑	2	3	4
5	6	7	●	9	10	11
12	13	14	◐	16	17	18
19	20	21	22	○	24	25
26	27	28	29	◑		

1	Venus passes 1.2° south of Spica, 2 P.M. EDT
4	Mars passes 2° north of Spica, 10 A.M. EDT
9	The Moon passes 8° south of Saturn, 6 P.M. EDT
11	The Moon passes 5° south of Mars, 4 A.M. EDT
	The Moon passes 0.3° south of Venus, 9 A.M. EDT
19	Mercury is at greatest western elongation (18°), 1 P.M. EDT
20	The Moon passes 5° north of Neptune, noon EDT
21	Jupiter is at opposition, 8 A.M. EDT
	Uranus is at opposition, 1 P.M. EDT
22	Jupiter passes 0.9° south of Uranus, 3 P.M. EDT
	Equinox (northern autumn/southern spring begins), 11 P.M. EDT
23	The Moon passes 7° north of Jupiter, 7 A.M. EDT
	The Moon passes 6° north of Uranus, 7 A.M. EDT
	Venus is at greatest brilliancy, 4 P.M. EDT
29	Venus passes 6° south of Mars, 2 A.M. EDT
30	Saturn is in conjunction with the Sun, 9 P.M. EDT

2010
Oct

S	M	T	W	T	F	S
					1	2
3	4	5	6	○	8	9
10	11	12	13	◑	15	16
17	18	19	20	21	●	23
24	25	26	27	28	29	◐
31						

9	The Moon passes 3° north of Venus, noon EDT	👁 🔭
	The Moon passes 4° south of Mars, 10 P.M. EDT	👁 🔭
16	Mercury is in superior conjunction, 9 P.M. EDT	
17	The Moon passes 5° north of Neptune, 6 P.M. EDT	🔭
20	The Moon passes 7° north of Jupiter, 7 A.M. EDT	👁 🔭
	The Moon passes 6° north of Uranus, 11 A.M. EDT	🔭
21	Orionid meteor shower peaks	👁
28	Venus is in inferior conjunction, 9 P.M. EDT	

A comet on a mission

Dozens of comets invade the inner solar system every year. Most never become more than faint wisps of light hiding among the stars. But this year offers a rarity: a periodic comet that will brighten enough to become a fine binocular comet and perhaps even reach naked-eye visibility. Comet 103P/Hartley will glow brightest these long October nights.

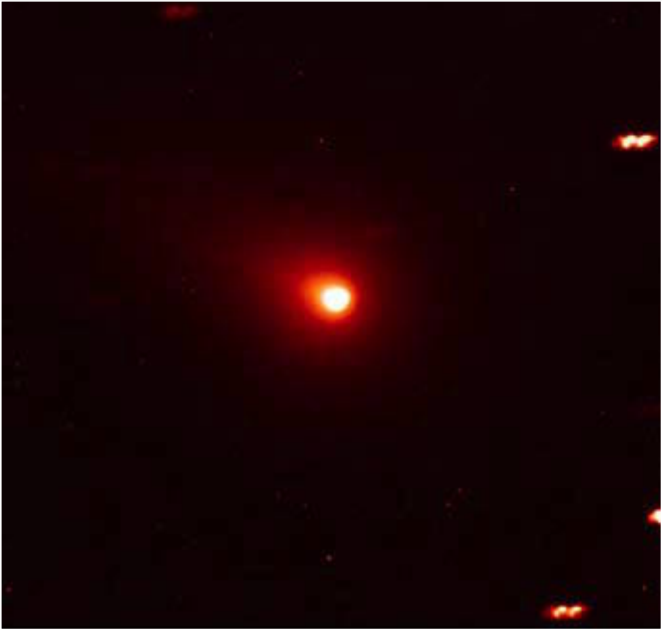
Assuming no one discovers a bright newcomer, 103P/Hartley will be the finest comet of 2010. Astronomer Malcolm Hartley discovered this comet in March 1986. It orbits the Sun every 6.5 years, but 2010 promises to be its best return yet. It comes closest to Earth (11 million miles away) October 20, when it should reach 5th magnitude. To top it off, Hartley remains visible nearly all night this fall.

As October begins, the comet lies in Cassiopeia, south of that constellation's W-shaped asterism. It soon moves into Perseus, setting up a glorious sight the night of October 8/9 when it passes the famous Double Cluster. This region climbs high in the northeast by late evening and passes nearly overhead shortly past midnight. The comet moves noticeably relative to the cluster pair during the night, offering some nice photo opportunities for astroimagers.

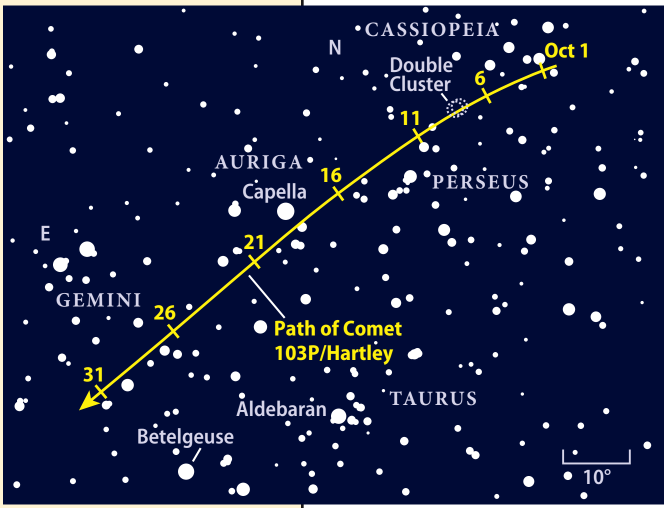
Hartley passes near the bright star Capella in mid-October, but moonlight starts to interfere. At Hartley's closest approach to Earth on the 20th, the comet should glow around 5th magnitude. A star this bright would be easy to see with naked eyes from a dark site. But comets are diffuse, and most observers say a comet has to reach 4th magnitude in a moonless sky to be visible without optical aid. The Full Moon October 22 won't make seeing it any easier.

As Earth observers follow Hartley, a NASA spacecraft will do likewise. Deep Impact visited Comet 9P/Tempel July 4, 2005. It released a probe that smashed into that comet, and a flyby spacecraft viewed this collision and sent the results to Earth.

NASA has renamed Deep Impact "Epoxi," and it will fly past Hartley November 4. Scientists will compare these observations with those of other comets to learn which features are primordial.



Comet 103P/Hartley glowed dimly when it passed through the inner solar system in 1997. This image shows the comet and its faint tail December 30 of that year. Tony Farnham/Lowell Observatory



The brightest returning comet of 2010 will be 103P/Hartley. It should peak at 5th magnitude when it comes closest to Earth in October. *Astronomy*: Theo Cobb

Venus gleams before dawn

2010 Nov

S	M	T	W	T	F	S
	1	2	3	4	5	●
7	8	9	10	11	12	◐
14	15	16	17	18	19	20
○	22	23	24	25	26	27
◑	29	30				

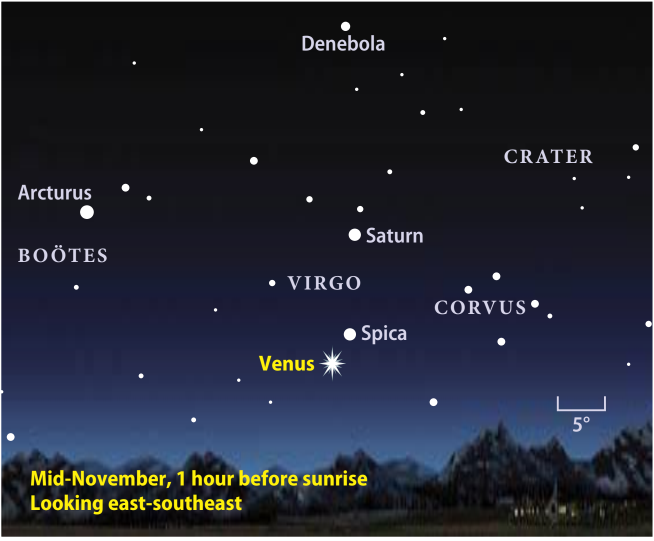
4	The Moon passes 8° south of Saturn, 2 A.M. EDT	👁 🔭
7	The Moon passes 1.6° south of Mars, 5 P.M. EST	👁 🔭
9	Asteroid Vesta is in conjunction with the Sun, 7 P.M. EST	
	Mars passes 4° north of Antares, 11 P.M. EST	👁 🔭
14	The Moon passes 5° north of Neptune, 1 A.M. EST	🔭
15	Mercury passes 2° north of Antares, 6 A.M. EST	👁 🔭
16	The Moon passes 7° north of Jupiter, 11 A.M. EST	👁 🔭
	The Moon passes 6° north of Uranus, 5 P.M. EST	🔭
17	Leonid meteor shower peaks	👁
20	Mercury passes 1.7° south of Mars, 8 P.M. EST	👁 🔭

Venus passes between the Sun and Earth in late October, briefly disappearing from view. But it reemerges in morning twilight just a week or so later and becomes a brilliant object before dawn in November and December.

On November 7, 10 days after its inferior conjunction, Venus rises an hours before the Sun. Shining at magnitude –4.3, the planet's brilliant light pierces the twilight glow. Look for it low in the east-southeast.

Just a week after that, it rises 2 hours before the Sun and stands 4° below Spica, the brightest star in Virgo. At magnitude –4.6, however, Venus shines about 175 times brighter than the star. Take some time in mid-November to view Venus through a telescope. Its large disk measures 54" across and sports a wafer-thin crescent just 9 percent lit.

Venus climbs away from the Sun throughout November. By the 30th, it pokes above the horizon more than 3 hours before the Sun and appears conspicuous well before twilight begins. A telescope reveals its 43"-diameter disk and one-quarter-lit crescent. Venus dominates the crisp December mornings. Its brightness peaks at magnitude –4.9 early in the month. But perhaps its best event comes on 2010's final morning, when a beautiful crescent Moon hangs to Venus' lower right.



Mid-November, 1 hour before sunrise
Looking east-southeast

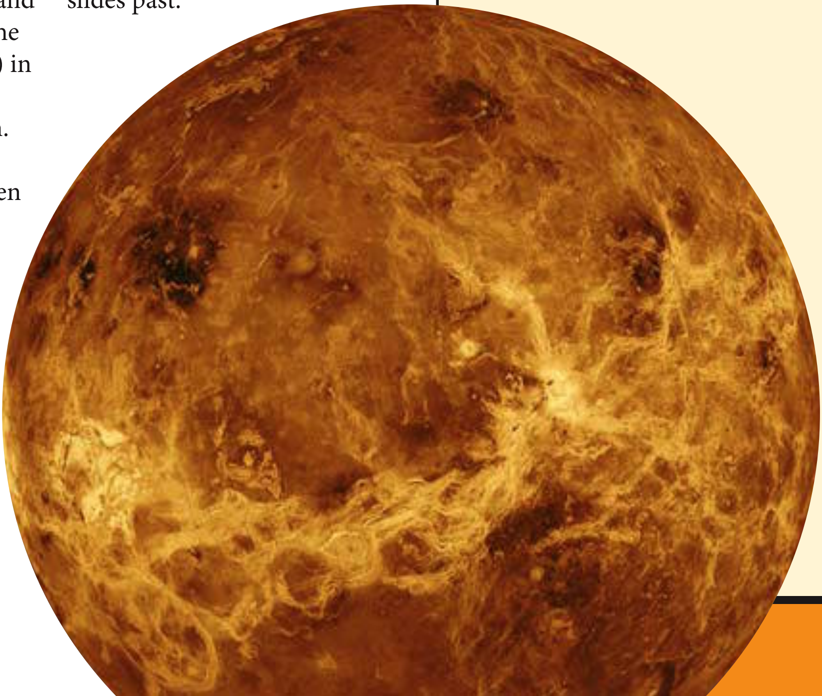
Venus gleams before dawn in late 2010 as it climbs above the bright twilight glow. In mid-November, it approaches Virgo's brightest star, 1st-magnitude Spica. *Astronomy:* Theo Cobb

When 2010 begins, Venus is lost in the Sun's glare. It appears in the evening sky in late February but doesn't become prominent until March. The planet climbs slowly away from the western horizon and remains stuck at magnitude –3.9 until June.

On June 20, the planet shines at magnitude –4.0 and lies less than 1° north of the Beehive star cluster (M44) in Cancer. Use binoculars to best view this conjunction.

Venus reaches greatest elongation August 19, when it lies 46° east of the Sun and shines at magnitude –4.5. Yet some of its best moments in August come from the company it keeps. On August 9, it passes 3° south of Saturn; on the 23rd, it passes 2° south of Mars. This planetary trio looks lovely every evening throughout this period. But the group truly shines August 12 and 13 when a waxing crescent Moon slides past.

Venus' volcanic surface stands out in this radar mosaic taken by the Magellan spacecraft. Earthbound observers, however, see only the planet's thick clouds. NASA/JPL



2010 Dec

S	M	T	W	T	F	S
			1	2	3	4
○	6	7	8	9	10	11
12	◑	14	15	16	17	18
19	20	●	22	23	24	25
26	◐	28	29	30	31	

1 Mercury is at greatest eastern elongation (21°), 11 A.M. EST

The Moon passes 8° south of Saturn, 1 P.M. EST

2 The Moon passes 6° south of Venus, 4 P.M. EST

4 Venus is at greatest brilliancy, 5 A.M. EST

7 The Moon passes 1.8° north of Mercury, 4 A.M. EST

11 The Moon passes 5° north of Neptune, 10 A.M. EST

13 The Moon passes 7° north of Jupiter, 9 P.M. EST

14 The Moon passes 7° north of Uranus, 1 A.M. EST

Geminid meteor shower peaks

19 Mercury is in inferior conjunction, 8 P.M. EST

21 Total lunar eclipse, 3 A.M. EST

Solstice (northern winter/southern summer begins), 7 P.M. EST

22 Asteroid Pallas is in conjunction with the Sun, noon EST

26 Pluto is in conjunction with the Sun, 8 P.M. EST

28 The Moon passes 8° south of Saturn, 10 P.M. EST

31 The Moon passes 7° south of Venus, 11 A.M. EST

Watch the Moon fade away

Earth's ruddy shadow will envelop the Full Moon December 20/21 during the first total lunar eclipse in nearly 3 years. Bill and Sally Fletcher

It's been a long drought since our last total lunar eclipse. On the night of February 20/21, 2008, the Moon passed completely into Earth's umbral shadow. Although several partial eclipses populated the intervening years, totality remained conspicuously absent. That changes the night of December 20/21.

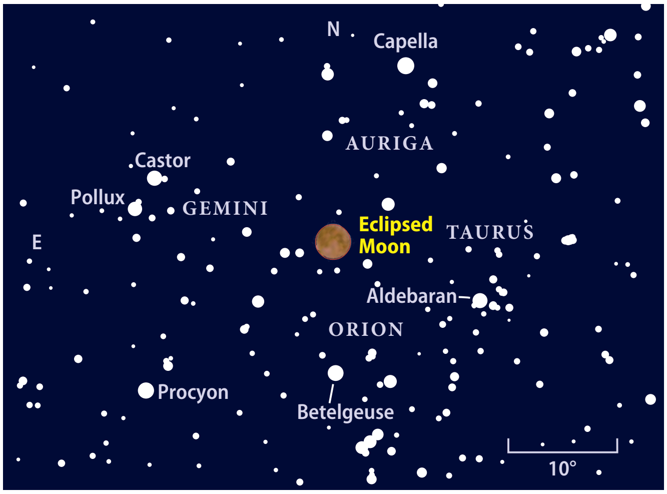
Observers throughout North America will see this entire eclipse if skies are clear. The partial phase begins at 1:32 A.M. EST December 21 (10:32 P.M. PST on the 20th). During the next 68 minutes, Earth's dark shadow will march across the lunar surface. You won't see much color at first because the dark shadow stands in stark contrast to the Moon's still-lit western regions. But as totality approaches, the Moon takes on a distinctly orange appearance.

Totality begins at 2:40 A.M. EST (11:40 P.M. PST) and lasts 73 minutes. The Moon's surface will be bathed in an eerie glow, which could be anything from a bright orange to a deep red. The color and darkness depend on Earth's atmosphere. Sunlight refracts through our atmosphere, and if lots of fine dust or aerosols are suspended in it, the eclipse will be darker.

The eclipse occurs less than 24 hours before the winter solstice. This places the Moon against the backdrop of eastern Taurus — about as far north as it gets. The adjacent winter stars will appear stunning, standing out much more clearly than they did when the Moon was full a couple of hours earlier. The Moon's color might resemble the glow from two bright and nearby reddish stars: Aldebaran in Taurus and Betelgeuse in Orion.

With more than an hour of totality, there's plenty of time to take a variety of photographs. Capture the whole scene with wide-angle images that include interesting foreground objects and the stars of Orion, Gemini, and Taurus. Shots through a telescope will capture subtle eclipse colors. Totality ends at 3:54 A.M. EST (12:54 A.M. PST), and the partial phases then will play out in reverse for a further 68 minutes.

Although the total eclipse highlights the lunar year, people in western North and South America, eastern Asia, Australia, and Pacific islands can watch a partial lunar eclipse June 26. Maximum eclipse arrives at 4:38 A.M. PDT, when just over half of the Moon will lie in shadow.



The eclipsed Moon will stand high in the sky for observers in North America. During totality, the Moon lies in Taurus near its border with Gemini and Orion. *Astronomy*: Theo Cobb

Wake up to a planet show

Visually interesting celestial events don't often coincide. But 2010 had one in September when Jupiter and Uranus reached opposition the same day. And 2011 gets off on a similar note: Both Mercury and Venus reach greatest western elongation within 24 hours of each other.

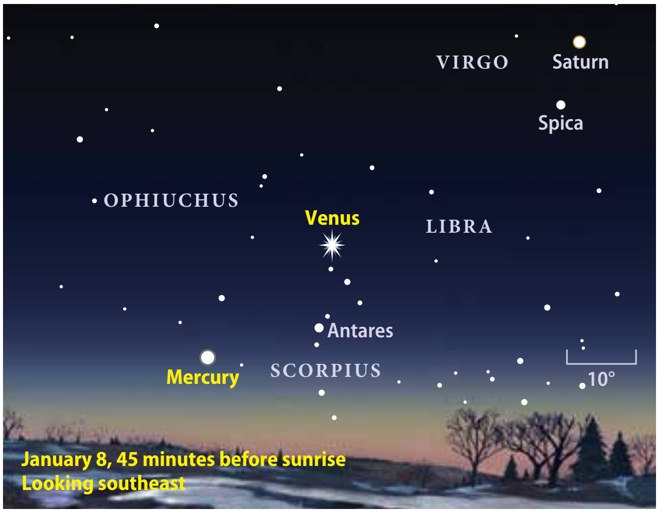
Venus arrives at this milestone January 8. It then lies 47° west of the Sun and appears nearly a third of the way up in the southeast 45 minutes before sunrise. Shining at magnitude –4.6, it easily beats every other object in the morning sky. Also look for 1st-magnitude Antares before dawn. This ruddy star lies directly below Venus and about half as high.

Mercury reaches greatest western elongation January 9. It then lies 10° high in the southeast 45 minutes before the Sun comes up. The innermost planet shines at magnitude –0.3 and appears quite prominent to Venus' lower left. If you can't spot it in the twilight glow with your naked eyes, binoculars will bring it into view.

Not only do these greatest elongations coincide, but they also are remarkably good ones for Northern Hemisphere observers. This is Mercury's best morning apparition of 2011, and Venus hasn't been this high before dawn in 4 years.

A telescope reveals similarities and differences between the two. Because they are at greatest elongation, both appear about half-lit with their bright hemispheres at lower left. But Venus is a larger planet and lies closer to Earth, so it appears much bigger than Mercury. On January 8, Mercury measures 7" across while Venus spans 25".

A waning crescent Moon passed below Venus (which itself appeared beneath Mercury) from Australia before dawn March 6, 2008. Mike Salway



Mercury and Venus share the morning sky in early January. The inner planets reach greatest elongation a day apart, with Venus lying higher in the twilight. *Astronomy*: Theo Cobb

2011
Jan

S	M	T	W	T	F	S
						1
2	3	●	5	6	7	8
9	10	11	◐	13	14	15
16	17	18	○	20	21	22
23	24	25	◑	27	28	29
30	31					

2 Jupiter passes 0.6° south of Uranus, 9 A.M. EST

The Moon passes 4° south of Mercury, 10 A.M. EST

3 Quadrantid meteor shower peaks

4 Partial solar eclipse, 4 A.M. EST

7 The Moon passes 5° north of Neptune, 7 P.M. EST

8 Venus is at greatest western elongation (47°), 11 A.M. EST

9 Mercury is at greatest western elongation (23°), 9 A.M. EST

10 The Moon passes 7° north of Uranus, 10 A.M. EST

The Moon passes 7° north of Jupiter, noon EST

25 The Moon passes 8° south of Saturn, 5 A.M. EST

29 The Moon passes 3° south of Venus, 11 P.M. EST

30 Asteroid Ceres is in conjunction with the Sun, 8 P.M. EST

2011 preview

Looking ahead to next year

Venus and Jupiter meet before dawn May 11, when the two brightest planets lie low in the east. This photo shows a similar scene from February 2008. Martin Graham

January 2011 is chock full of great sights. Both Mercury and Venus shine brightly before dawn and lie about as high as they can get. January's other outstanding event is the Quadrantid meteor shower. It peaks the night of January 3/4, the same night as New Moon. If the weather cooperates (a big if at this time of year), observers could see more than 100 meteors per hour before dawn.

Venus remains a morning object until early summer. As it crosses the starry background, it joins Jupiter in the predawn twilight May 11. Anytime the two brightest planets meet is special, but this one stands out. First, they lie just 1 Moon-width apart. And second, Mars lies within 5° of the pair and Mercury within 2° that same morning.

Eclipses play a central role in the 2011 highlights. The Moon twice travels through Earth's shadow, bringing totality to about half the world each time. The June 15 eclipse features 101 minutes of totality — it doesn't get much better than that. Those in the Eastern Hemisphere will have ringside seats for this event. December 10 brings a second dose of totality. The total phase lasts half as long as during June, but viewers in western North America will see this eclipse shortly before dawn.

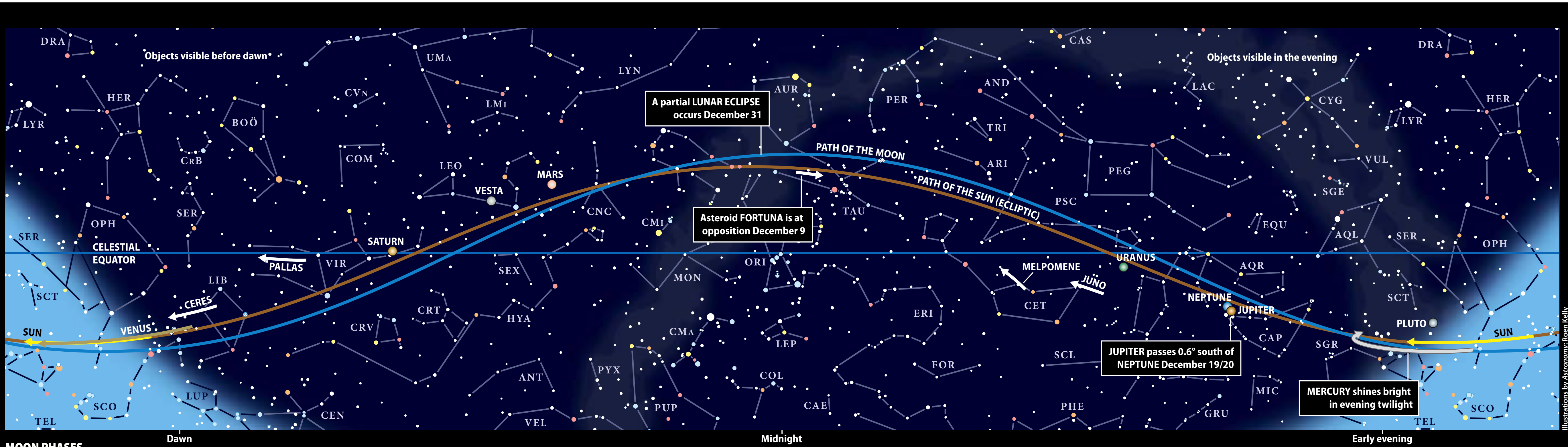
Solar eclipses don't fare as well. Although the Moon crosses the Sun's face four times in 2011, all result in partial eclipses. We'll have to wait until November 2012 to see the next total solar eclipse.

Two total lunar eclipses take place in 2011. The second, on December 10, occurs before dawn in North America and should mimic this February 2008 eclipse. Tunç Tezel

The Quadrantid meteor shower should be the meteor highlight of 2011. The normally prolific shower peaks in early January when the Moon is out of the sky. Frankie Lucena

Planets in December 09

This map unfolds the entire night sky from sunset (at right) until sunrise (at left).
Arrows and colored dots show motions and locations of solar system objects during the month.


Objects visible before dawn
DRA
LYR
HER
BOÖ
CRB
CVN
UMA
LMI
COM
LEO
VESTA
MARS
LYN
SER
OPH
CELESTIAL EQUATOR
SER
SCT
SUN
VENUS
CERES
LIB
PALLAS
VIR
SATURN
SEX
CRT
CRV
HYA
ANT
LUP
SCO
TEL
CEN
VEL
CNC
CMI
MON
ORI
CMA
LEP
PYX
PUP
COL
CAE
AUR
PER
AND
TRI
ARI
TAU
PATH OF THE MOON
PATH OF THE SUN (ECLIPTIC)
CAS
ERI
FOR
CET
MELPOMENE
JUNO
PSC
PEG
LAC
URANUS
AQR
NEPTUNE
JUPITER
SCL
PHE
CAP
MIC
GRU
EQU
Objects visible in the evening
CYG
LYR
VUL
SGE
AQL
SER
OPH
HER
DRA
SCT
PLUTO
SUN
SGR
SCO
TEL
Dawn
Midnight
Early evening

A partial LUNAR ECLIPSE occurs December 31

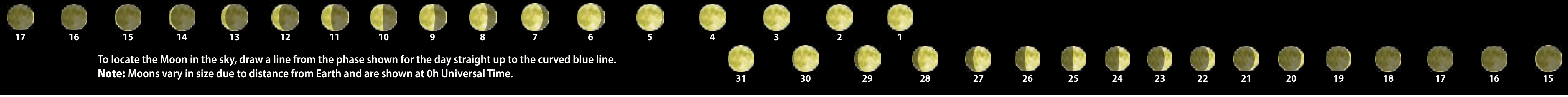
Asteroid FORTUNA is at opposition December 9

JUPITER passes 0.6° south of NEPTUNE December 19/20

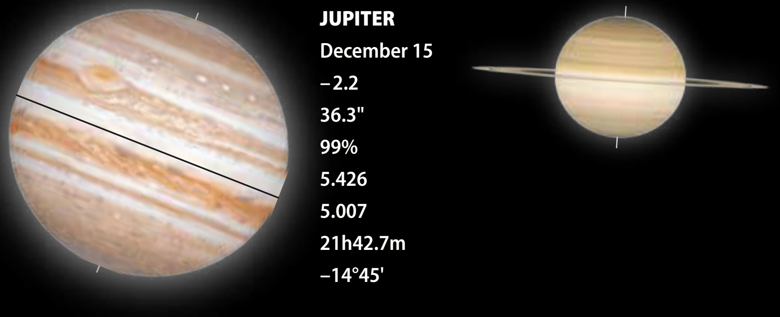
MERCURY shines bright in evening twilight

Illustrations by *Astronomy*: Roen Kelly

MOON PHASES


17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
31
30
29
28
27
26
25
24
23
22
21
20
19
18
17
16
15

To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.
Note: Moons vary in size due to distance from Earth and are shown at 0h Universal Time.

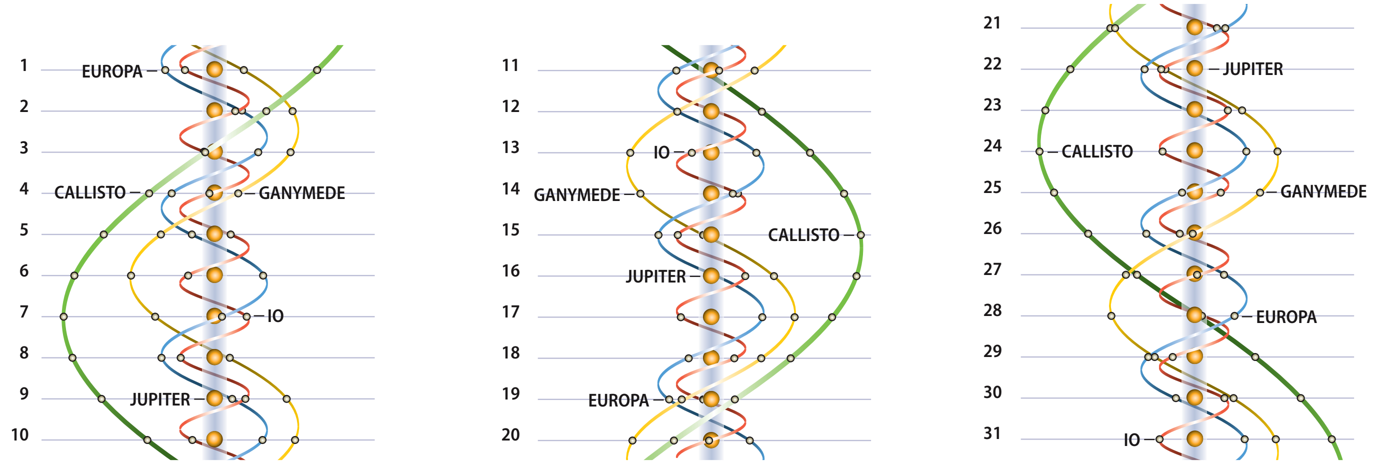


PLANETS	**MERCURY**	**VENUS**	**MARS**	**CERES**	**JUPITER**	**SATURN**	**URANUS**	**NEPTUNE**	**PLUTO**
Date	December 15	December 1	December 15	December 15	December 15	December 15	December 15	December 15	December 15
Magnitude	–0.6	–3.9	–0.4	8.9	–2.2	1.0	5.8	7.9	14.1
Angular size	6.2"	10.0"	11.1"	0.4"	36.3"	17.3"	3.5"	2.2"	0.1"
Illumination	72%	99%	93%	99%	99%	100%	100%	100%	100%
Distance (AU) from Earth	1.090	1.673	0.844	3.543	5.426	9.604	20.079	30.490	32.720
Distance (AU) from Sun	0.372	0.724	1.613	2.692	5.007	9.470	20.097	30.025	31.754
Right ascension (2000.0)	18h56.2m	15h46.6m	9h31.1m	15h44.6m	21h42.7m	12h17.2m	23h34.1m	21h45.8m	18h10.7m
Declination (2000.0)	–24°55'	–19°07'	17°54'	–15°23'	–14°45'	0°33'	–3°37'	–13°55'	–18°17'

10"
S
W E
N

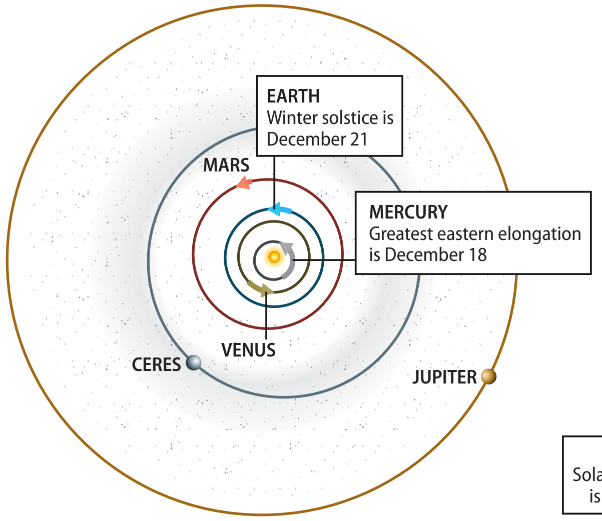
Jupiter's moons

Dots display positions of Galilean satellites at 9 P.M. EST on the date shown.
South is at the top to match the view through a telescope.



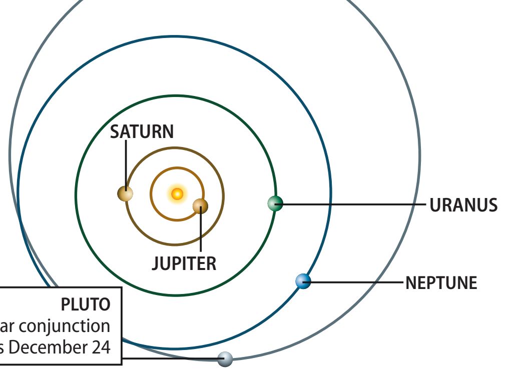
The planets in their orbits

Arrows and dots show planets' positions during December.


MARS
VENUS
CERES
JUPITER

EARTH
Winter solstice is December 21

MERCURY
Greatest eastern elongation is December 18


SATURN
JUPITER
URANUS
NEPTUNE

PLUTO
Solar conjunction is December 24

StarDome

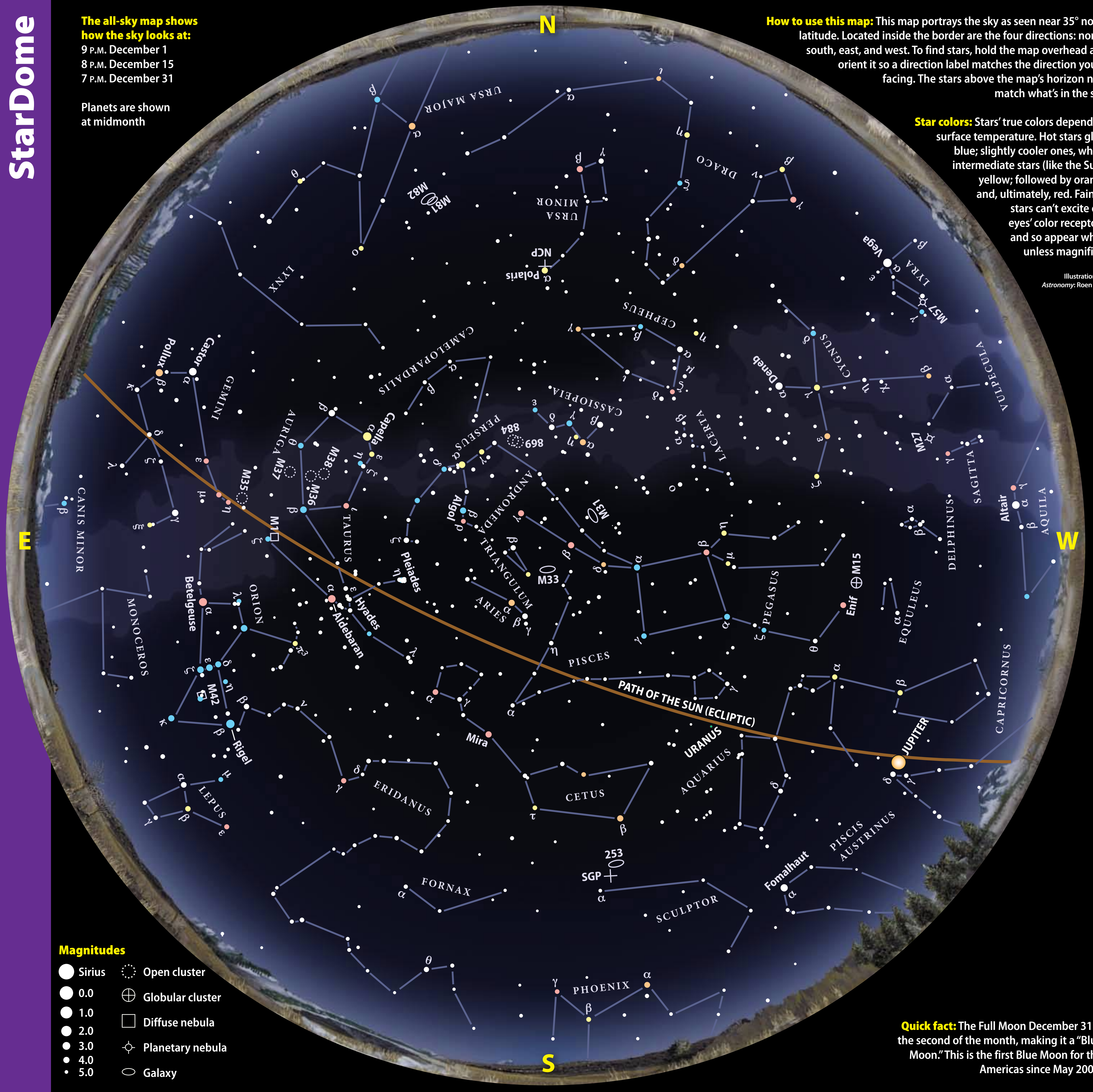
The all-sky map shows how the sky looks at:
9 P.M. December 1
8 P.M. December 15
7 P.M. December 31

Planets are shown at midmonth

How to use this map: This map portrays the sky as seen near 35° north latitude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

Star colors: Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.

Illustrations by *Astronomy*: Roen Kelly


N
E
S
W
URSA MAJOR
M81
M82
URSA MINOR
NCP
Polaris
DRACO
LYNX
CEPHEUS
CAMELOPARDALIS
Vega
LYRA
M57
CYGNUS
Deneb
VULPECULA
CASSIOPEIA
LACERTA
M27
SAGITTA
Altair
AQUILA
DELPHINUS
M15
Enif
EQUULEUS
PEGASUS
CAPRICORNUS
JUPITER
PATH OF THE SUN (ECLIPTIC)
URANUS
AQUARIUS
PISCIS AUSTRINUS
Fomalhaut
SCULPTOR
253
SGP
PHOENIX
FORNAX
CETUS
Mira
ERIDANUS
PISCES
ARIES
TRIANGULUM
M33
ANDROMEDA
M31
Algol
PERSEUS
884
869
Capella
AURIGA
M37
M38
M36
M35
M1
TAURUS
Pleiades
Hyades
Aldebaran
ORION
Betelgeuse
M42
Rigel
LEPUS
MONOCEROS
CANIS MINOR
GEMINI
Castor
Pollux

Magnitudes
- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

Quick fact: The Full Moon December 31 is the second of the month, making it a "Blue Moon." This is the first Blue Moon for the Americas since May 2007.

December 09

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

Calendar of events

1 Uranus is stationary, midnight EST

2 Full Moon occurs at 2:30 A.M. EST

4 The Moon is at perigee (225,856 miles from Earth), 9:18 A.M. EST

6 The Moon passes 6° south of Mars, 10 P.M. EST

8 Last Quarter Moon occurs at 7:13 P.M. EST

9 Asteroid Fortuna is at opposition, 11 A.M. EST

10 The Moon passes 8° south of Saturn, 6 A.M. EST

13 Geminid meteor shower peaks

16 New Moon occurs at 7:02 A.M. EST

18 The Moon passes 1.4° north of Mercury, 3 A.M. EST

Mercury is at greatest eastern elongation (20°), noon EST

19 Jupiter passes 0.6° south of Neptune, midnight EST

20 The Moon is at apogee (252,109 miles from Earth), 9:53 A.M. EST

21 The Moon passes 4° north of Neptune, 10 A.M. EST

The Moon passes 4° north of Jupiter, 10 A.M. EST

Mars is stationary, 11 A.M. EST

Winter solstice occurs at 12:47 P.M. EST

23 The Moon passes 6° north of Uranus, 9 P.M. EST

24 First Quarter Moon occurs at 12:36 P.M. EST

Pluto is in conjunction with the Sun, 1 P.M. EST

26 Mercury is stationary, 4 A.M. EST

31 Full Moon occurs at 2:13 P.M. EST

Special observing date

31 A partial lunar eclipse occurs for observers in Africa, Asia, Australia, Europe, and far northern North America.

See tonight's sky in Astronomy.com's STARDOME

Astronomy magazine

— *Continued from page 36*

through a telescope than it did at opposition in August, its disk still spans 36". That's big enough to show lots of detail, and the giant planet never fails to impress. Look for fine features at the borders between the dark belts and lighter zones.

This year provides an extra treat for Jupiter observers. Throughout 2009, the four bright Galilean moons undergo a series of so-called mutual events. In some, one moon passes in front of another and occults it from view. In others, a moon's shadow falls on another and partially or totally eclipses it.

December offers two good events for North American observers. On December 2 at 9:08 P.M. EST, Io passes in front of Europa, and the pair dims by 45 percent. The second event occurs December 14 at 7:26 P.M. EST (during twilight in western North America). Europa then occults Io, which produces a 23 percent drop in their combined brightness.

Jupiter lies among the relatively dim background stars of Capricornus the Sea Goat. On December 20/21, the planet's eastward motion relative to the stars carries it due north of 3rd-magnitude Deneb Algedi (Delta [δ] Capricorni).

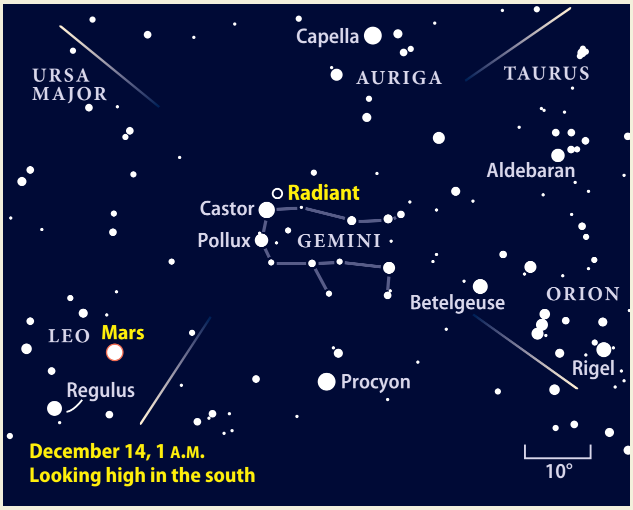
Even more significantly, Jupiter's motion brings it within a single Moon-width of **Neptune** in mid-December. The two will lie in the same low-power field of view. (You also can spot them through tripod-mounted binoculars.)

Jupiter passes 34" due south of Neptune December 19. Take advantage of this rare alignment to track down 8th-magnitude Neptune, which glows 10,000 times fainter than Jupiter. At higher magnification through a telescope, Neptune shows a blue-gray disk that spans 2.2".

Look significantly higher in the southwestern sky and you'll find **Uranus**. It glows at magnitude 5.8 and shows up easily through binoculars. A telescope reveals the planet's

Martin Ratcliffe *provides professional planetarium development for Sky-Skan Inc. in Nashua, New Hampshire. Meteorologist* **Alister Ling** *works for Environment Canada in Edmonton, Alberta.*

Meteor watch



The Geminid meteor shower **peaks before dawn December 14. With the Moon out of the way, observers with dark skies may see 100 meteors per hour or more.** *Astronomy*: Roen Kelly

A double dose of meteors

December bodes well for meteor observers, with two annual showers peaking with little interference from the Moon. The always reliable Geminids, one of the year's strongest showers, peaks the night of December 13/14. The highest rates come in the hours after midnight when the radiant climbs high. Observers under dark skies may see more than 100 meteors per hour.

It's best to look at least 30° from the shower's radiant, which lies in northern Gemini. The shower derives from the asteroid 3200 Phaethon, which many astronomers suspect is the nucleus of a dead comet. As with any observing this time of year, bundle up against the cold and bring along something warm to drink.

The month's second shower is the Ursids, whose radiant lies near Kochab (Beta [β] Ursae Minoris). This minor shower usually delivers around 10 meteors per hour, but rates sometimes rise as high as 50 per hour. The Ursids peak before dawn December 22.

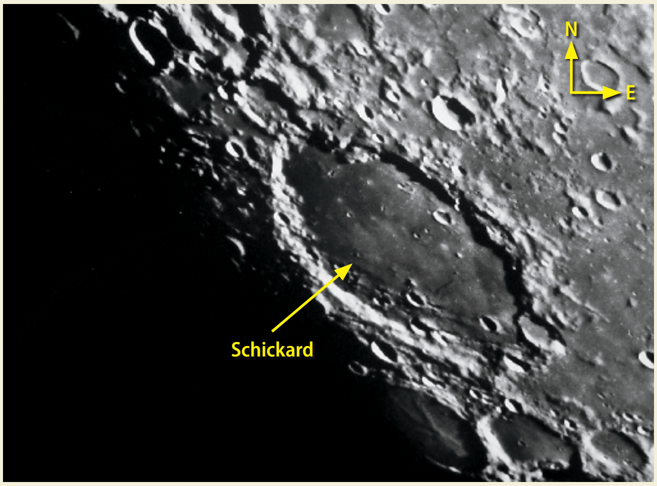
Rising Moon

A crater's life: flooded, sprayed, and strafed

In the opening days of December, sunlight beats down on the crater Schickard in the Moon's southwestern quadrant. This full illumination reveals a two-faced crater with stripes. A first glance picks up a swath of lighter gray painted across the middle of this timeworn feature.

Schickard encapsulates much of the Moon's history. A giant impact some 4 billion years ago — during the first wave of heavy bombardment — gave birth to this 140-mile-wide depression. Lava soon welled up and covered Schickard's central peaks. Then, the giant Orientale impact to the west sprayed the whole region with lighter-hued material. A final surge of lava covered Schickard's northern and southern portions, but it did not rise high enough to erase the lighter central stripe. Impacts during the past few billion years pocked the crater's lava surface and battered its rim.

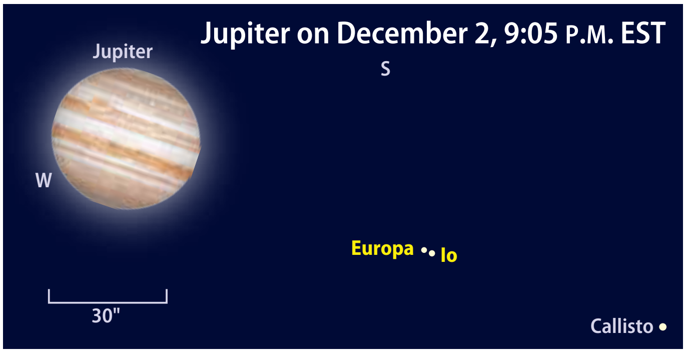
Sunrise returns to Schickard December 28 — the same night the Moon passes through the Pleiades star cluster (M45). The low Sun and rough lunar landscape conspire to cast plenty of shadows and camouflage the different shades of material. In just a couple of days, however, the stripe returns to prominence.



The crater Schickard **lies in the Moon's southwest and comes into view shortly before Full Moon. Look for a lighter stripe crossing the crater's middle as the Sun climbs higher in Schickard's sky.** *Consolidated Lunar Atlas*/UA/LPL

When to view **the planets**

EVENING SKY	MIDNIGHT	MORNING SKY
Mercury (southwest)	Mars (east)	Mars (southwest)
Jupiter (southwest)		Saturn (south)
Uranus (south)		


Jupiter on December 2, 9:05 P.M. EST

Jupiter's moon Io passes in front of Europa after sunset December 2. The pair's light dims by almost one-half when Io covers most of Europa starting at 9:08 P.M. EST. *Astronomy*: Roen Kelly

3.5"-diameter disk, which has a distinct blue-green hue.

Although Jupiter and Neptune set by 10 P.M. local time, Uranus remains above the horizon until near midnight. To find Uranus, start with the Great Square of Pegasus. Then, look south of the Square and pick up the Circlet asterism of Pisces. Finally, shift your gaze about a Circlet's diameter farther south. Uranus lies in this bland sky region, 6° due west of the 5th-magnitude star 27 Piscium.

As Jupiter dips low in the west, it gains a rival in the east. **Mars** is rapidly approaching its best appearance in 2 years. The Red Planet rises before 10 P.M. local time December 1 and 2 hours earlier by month's end. The best views through a telescope come from midnight on, when the planet's higher altitude offers less distortion from turbulence in Earth's atmosphere.

Mars brightens from magnitude –0.1 to –0.7 during December, which makes it an obvious addition to the stars of Leo the Lion. Through a telescope, the planet's disk grows from 10" to nearly 13", although that's still small. You'll need patience and steady air to get good views. Many observers like to capture video frames and then use image-processing software to select the best from moments of good seeing.

Mars' shrinking north polar cap will be on prime display because the planet's northern hemisphere now tilts in Earth's direction. Other areas on view include the dark triangular albedo feature Syrtis Major, which lies near the disk's center around midnight during December's first week. In the next week, the broad Amazonis Basin and the Tharsis ridge region appear. These areas contain fewer dark features.

Once December's third week rolls around, the dark features around Solis Lacus are on display as Mars rises. Although this region rotates off the disk quickly, it stays visible longer as December winds down.

Mars' apparent path against the backdrop of Leo changes direction this month. During December's first 3 weeks, the planet moves in its normal easterly direction. But watch carefully, and you'll see its progress slow. On December 21, it becomes stationary, and then it begins moving westward, or retrograde.

An easy way to track Mars' motion is to watch its position relative to two stars in Leo's conspicuous Sickle asterism: 4th-magnitude Mu (μ) and 3rd-magnitude Epsilon (ε) Leonis. Mars lines up perfectly with this pair December 8. The planet then moves out of alignment for a while, but retrograde movement brings it back into line with the two stars December 29. Mars' retrograde motion will carry it into Cancer the Crab early

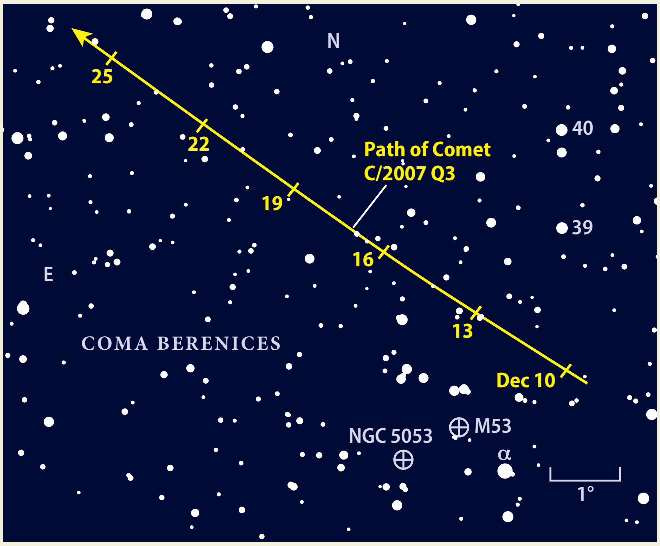
Comet search

Clusters and a comet congregate in Coma

Stargazers always hope an unexpectedly bright comet will grace the evening sky. Barring such luck, we'll have to wait until around 2 A.M. to see a decent comet. That's when the 10th-magnitude interplanetary snowball known as C/2007 Q3 (Siding Spring) rises in the east. If you're out in the wee hours during mid-December to watch the Geminid meteor shower, take at least a few minutes for comet viewing before heading home.

Comets and meteor showers have more in common than you might think. Comets glow when sunlight reflects from the vast amount of fine dust they release as their ices evaporate. If Earth sweeps through dust trails left behind by comets, the motes burn up in our atmosphere and become "shooting stars." Comet C/2007 Q3 is making its first trip through the inner solar system, so it hasn't yet generated a meteor-producing dust stream.

Last month this comet passed in front of the realm of galaxies in the constellations Virgo and Coma Berenices. During the New Moon weekend of December 12 and 13, it sails past the globular clusters M53 and NGC 5053 in Coma Berenices. Compare the roundish shapes of the globulars with that of the comet. Each brightens toward its center, but in a noticeably different way.



Comet C/2007 Q3 (Siding Spring) should glow at 10th magnitude this month. Compare its appearance with the nearby globular clusters M53 and NGC 5053 in Coma Berenices. *Astronomy*: Roen Kelly

Locating **asteroids**

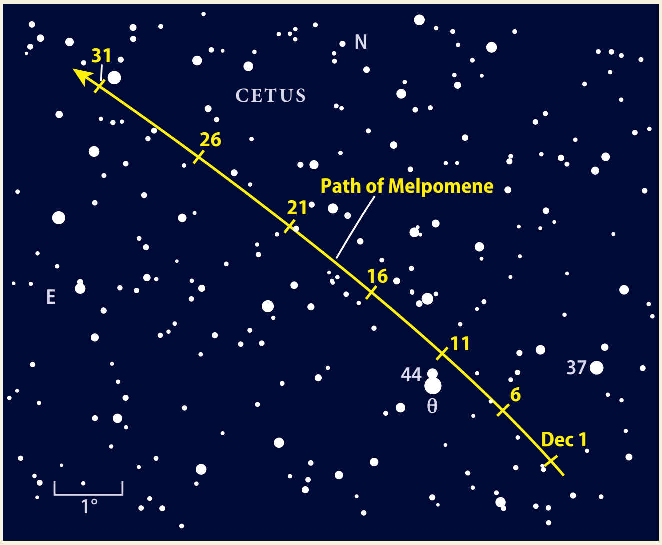
Melpomene swims with the Whale

The larger rocks that orbit the Sun betray their nature by shifting position from night to night. It's a characteristic astronomers continue to use today to discover ever-smaller boulders. This month, you can practice the technique by following asteroid 18 Melpomene as it crosses the constellation Cetus the Whale, which lies in the southern sky after darkness falls.

From December 6 to 13, Melpomene tracks within 1° of the 4th-magnitude star Theta (θ) Ceti. One degree is a bit wider than a typical low-power field of view for a starter scope. Apart from Theta and its 6th-magnitude companion, 44 Ceti, 9th-magnitude Melpomene is pretty much the next brightest object in this area.

On December 21, you won't have to wait an entire night to notice Melpomene's position change. Within just 2 or 3 hours, this main-belt asteroid slides slowly away from an 8th-magnitude background star. Use the chart at right to zero in on the star, then bump up the magnification and follow the asteroid's movement.

English astronomer John Hind discovered Melpomene in June 1852. Today, we know it measures 88 miles across and reflects 22 percent of the sunlight that strikes it. This makes it considerably more reflective than most of the Moon's surface.



Melpomene glows at 9th magnitude among the background stars of Cetus. During December's second week, it skirts the 4th-magnitude star Theta (θ) Ceti. *Astronomy*: Roen Kelly

next year in prelude to its January 29 opposition.

Saturn rises 4 hours after Mars and appears high in the south shortly before dawn. The ringed planet brightens slightly, reaching magnitude 0.9 in the second half of December. It sits among the stars of Virgo the Maiden, where it's a near match for that constellation's brightest star, Spica. Contrast Saturn's golden hue with Spica's blue-white color. Saturn stands due north of a waning crescent Moon December 10.

The rings provide a stunning view through a telescope. They span 39", more than double the 17" diameter of Saturn's disk. And they tilt 5° to our line of sight by year's end — the maximum during 2009. They will continue to widen for the next several years. It will be 2025 before the rings tilt edge-on like they did this past summer.

The angle between the Sun and Saturn as viewed from Earth reaches 90° December 25. At this so-called quadrature, Saturn's shadow falls farthest west where it crosses the rings behind the planet. The shadow shows up easily under moderate magnification and lends a powerful 3-D effect to Saturn.

Saturn's brightest moon, Titan, shows up through any telescope. During each 16-day orbit of Saturn, Titan passes just above and just below the planet. You'll find it near Saturn the mornings of December 1, 9, 17, and 25.

The outer moon Iapetus begins December with its brighter side facing Earth. It then lies 8' west of Saturn and glows at 10th magnitude. By the morning of December 21, Iapetus stands due north of Saturn. As Iapetus moves east of Saturn late this month, its darker side turns toward us and the two-faced moon dims noticeably.

Venus remains lost in the Sun's glare all month. The inner planet will pass behind the Sun as seen from Earth (an alignment known as superior conjunction) in January.

Anthony Ayiomamitis

Earth's shadow covered the Moon's north pole during this September 2006 eclipse. On December 31, our shadow kisses the lunar south pole.

The year's final day brings a partial **lunar eclipse**. Earth's dark umbral shadow covers 8 percent of the Moon at maximum, so the eclipse won't be spectacular. Still, it's the only decent lunar eclipse of 2009.

The best views will come to residents of Europe, Asia, Africa, and Australia. In North America, those in the far northeast will see the end of the eclipse, and those in the far northwest will see the eclipse begin. Maximum eclipse occurs at 19h23m Universal Time (2:23 P.M. EST, 10:23 A.M. AKST).

Ask Astro

Astronomy's experts from around the globe answer your cosmic questions.

Can we bring Hubble home?

Q: Is there a plan to retrieve the Hubble Space Telescope from space to preserve it in the Smithsonian Institution or elsewhere for future generations to appreciate? — **Joseph Rusz,** Herndon, Virginia

A: No. NASA's space shuttle fleet is scheduled to go out of service in 2010. And after that, neither the United States nor any other nation will have a space vehicle capable of returning such a large piece of equipment to Earth.

Over the years, some NASA officials have mused about bringing Hubble back to Earth at the end of its operational life and putting it in the Smithsonian Air and Space Museum in Washington, D.C. Unfortunately, cost and safety issues argue against the idea.

Simply retrieving the 24,500-pound (11,100 kilograms) telescope would cost approximately $1 billion for a dedicated space shuttle mission. That is a significant fraction of the cost of building a new space telescope. Also, given the inherent dangers of space flight, such a mission might be seen as frivolous in risking the lives of astronauts for the sake of salvaging a museum piece.

On the last servicing mission to Hubble in May, space shuttle *Atlantis* astronauts outfitted the telescope with a universal docking adapter called a Soft Capture and Rendezvous System (SCRS). At some point in the future, a robotic spacecraft will dock with the telescope and bring it into a controlled reentry over the Pacific Ocean. — **Ray Villard,** Space Telescope Science Institute, Baltimore

The Hubble Space Telescope looked clean and spiffy on April 25, 1990, when astronauts on the space shuttle Discovery nudged the space observatory into orbit. NASA/Smithsonian Institution/Lockheed Corporation

BLACK HOLE BIRTH

Q: How do supermassive black holes form at the centers of galaxies? — **Kenneth Klein,** New Bern, North Carolina

A: The largest supermassive black holes contain billions of times the Sun's mass. **The simplest explanation is that a relatively small "stellar-mass" black hole forms early in the universe and grows incrementally over the eons to develop into the jumbo variety.**

A stellar-mass black hole develops when a star containing up to 20 times the Sun's mass collapses to form a compact remnant whose gravity is so intense that not even light can escape its grip. Such a black hole would have a lot of company in the crowded galactic center. It could swallow nearby stars and merge with other black holes, increasing in mass.

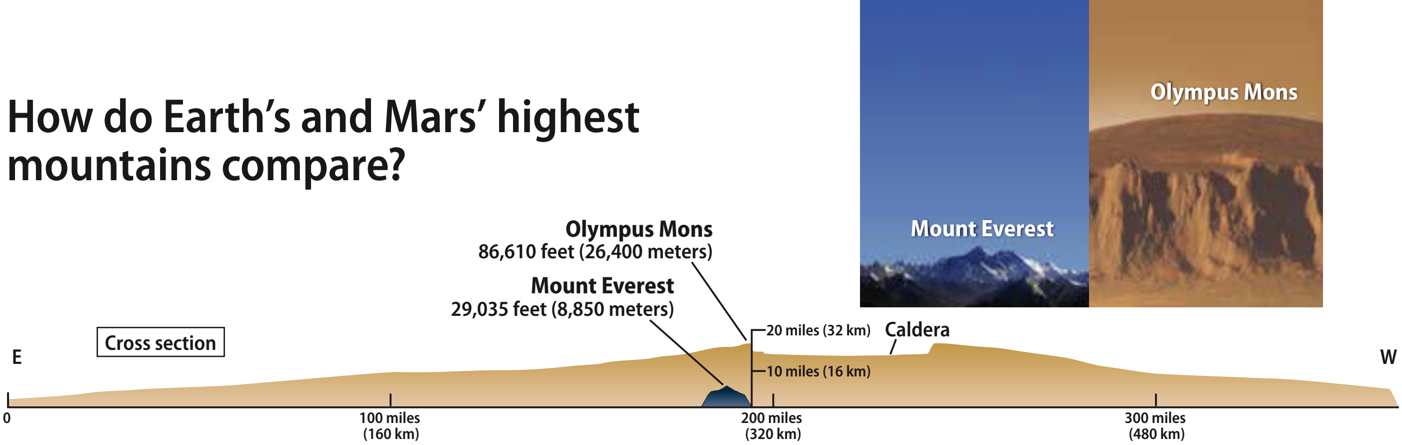
Various processes also drive gas toward the centers of galaxies, "feeding" black hole growth. Galaxy collisions, for example, have this effect. Calculations suggest that this "gas accretion" process could double a black hole's size every 10 to 40 million years.

This doubling rate accounts for the 1-billion-solar-mass black holes we see in galaxies dating to around 1 billion years after the Big Bang. But if astronomers were to find a 1-billion-solar-mass black hole only 100 million years after the Big Bang, the accretion hypothesis would be in big trouble!

There is an alternative theory to accretion. Some astronomers believe that under certain conditions, a massive gas cloud could collapse directly to form a supermassive black hole. So far, we have not found evidence for this. As we peer further back into the history of the universe, we hope to learn more about the birth and evolution of giant black holes. — **Eliot Quataert,** Theoretical Astrophysics Center, University of California at Berkeley

Find out what it's like on Uranus at www.Astronomy.com/toc.

How do Earth's and Mars' highest mountains compare?



Mars' Olympus Mons, the tallest known mountain in the solar system, is 86,610 feet (26,400 meters) high. It easily dwarfs Mount Everest, Earth's highest mountain on land, both in height and in width. *Astronomy*: Roen Kelly

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MARTIAN MOUNTAIN-MAKING

Q: How did Olympus Mons get to be so tall? Is it because the gravity on Mars is weaker than that on Earth? — **Mike Watson,** Edmonton, Alberta

A: On Mars, mountains form by repeated volcanic eruptions. The largest volcano on the Red Planet is Olympus Mons, which stands 16.4 miles (26.4 kilometers) tall. During its construction, molten material (magma) repeatedly erupted onto the martian surface from a channel (vent) connected to an underground supply called a magma chamber.

The maximum height of a volcano is limited by how high the magma chamber can lift the molten rock — similar to blowing water up through a straw. Mars' gravity offers less resistance, which means magma rises higher at a given pressure than on Earth. But the chamber pressure on Mars would be lower because of the weaker gravity. The effects of gravity and chamber pressure cancel each other out.

Ultimately, volcanic mountains on Mars are higher because they have more time to grow. Earth's dynamic crust limits the length of time magma can continue to erupt onto the surface. Our planet's semirigid outer shell, called the "lithosphere," is broken into tectonic plates in continuous motion. Plate motion tends to "shut off" a volcano's magma supply after a geologically brief period.

Mars lacks plate tectonics, and this explains why Olympus Mons was able to grow so high. Scientists think Olympus Mons has remained active for most of Mars' history — meaning 4.5 billion years of eruptions building on each other to make the largest volcano and mountain in the solar system. — **Margarita Marinova,** California Institute of Technology, Pasadena

Send your questions via e-mail to: **askastro@astronomy.com**; or write to **Ask Astro, P. O. Box 1612, Waukesha, WI, 53187.** Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

ASTROBIOLOGY

Q: Does Titan have the requirements to support life? — **Alex Arslanian,** Buenos Aires, Argentina

A: Yes, chemistry and conditions exist on Titan that could theoretically give rise to life. Astrobiology's best definition for life is a self-sustaining chemical system capable of Darwinian evolution. It is easy to be "Earth-centric" and assume that living systems are necessarily structured at the molecular level like Earth life. Terrestrial life lives in environments significantly warmer than on Titan but with considerably less organic material than exists on the saturnian moon.

Thinking more broadly, however, as long as Titan has a source of free energy — and it does, from sunlight and other sources — it is conceivable that life might live in the oceans of methane on the surface of Titan. Alternatively, it is likely that Titan has liquid water-ammonia mixtures below its surface. These, too, could harbor life — again, differing in its molecular details from life on Earth.

A National Research Council report, *The Limits of Organic Life in Planetary Systems* (2007), found good reason to think any liquid will do as a "necessary ingredient," and this doesn't need to be water. This is further discussed in *Life, the Universe, and the Scientific Method* (FfAME Press, 2009). When contemplating the possibilities for life in the universe, it is best to think outside the box. — **Steven Benner,** Foundation for Applied Molecular Evolution, Gainesville, Florida

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CELESTIAL EXTREMES

Q: What is the smallest star in the universe, and where is it?
— **Nikunj Rawal,** Surat, India

A: In 2008, a team of astronomers led by Notre Dame's David Bennett announced the discovery of a small rocky planet 3,000 light-years from Earth orbiting a small star. This star, called **MOA-2007-BLG-192L, is the leading candidate for the smallest hydrogen-burning "normal" star known.** It lies in the constellation Sagittarius.

The data astronomers have on MOA-2007-BLG-192L allow for a range of masses. If the star has as little as 6 percent of the Sun's mass, it would be a "brown dwarf." Brown dwarfs produce some energy but not by nuclear fusion. These are not "normal" stars like the Sun.

But MOA-2007-BLG-192L may be up to 9 percent of the Sun's mass. In that case, it would be a "red dwarf" star with enough mass to sustain fusion. If MOA-2007-BLG-192L is a red dwarf, it would be 100 times brighter than if it were a brown dwarf, but still 1,000 times fainter than the Sun. Bennett and his colleagues plan observations with the Hubble Space Telescope to settle the uncertainty over MOA-2007-BLG-192L's mass. — **Daniel Pendick,** Science writer, Goddard Space Flight Center, Greenbelt, Maryland

Beginning observing

Top 10 winter Milky Way treats

These must-see star clusters and nebulae look their best in this season's crisp air. **by Michael E. Bakich**

On clear winter nights, scanning along the Milky Way reveals many splashy objects. Although the air may be cold, if it's clear you'll hardly notice the weather when you gaze at these deep-sky treats. So, set your scope outside to cool (because heat currents distort the view), and get ready for a starry adventure.

For this list, I've gathered 10 of winter's best deep-sky objects. By "deep-sky," I mean an object that lies outside the boundary of the solar system. Such objects include star clusters, nebulae, and galaxies (but no galaxies are on this list).

As you view these targets through your telescope, look for features that make each one different from the others. Look for double stars and patterns within clusters. Examine the shapes and colors of nebulae. Take a look at a previously viewed object for comparison. Don't rush while viewing, and take some notes. That way, you will observe these objects and not just check them off a list.

Winter's top objects

These 10 sky treats will get you started observing winter's many types of deep-sky objects. For best results, set up your scope at a dark site.

Object	R. A.	Dec.	Mag.	Size
M37	5h52m	32°33'	5.6	15'
M45	3h47m	24°07'	1.2	110'
M1	5h35m	22°01'	8.0	6' by 4'
M35	6h09m	24°21'	5.1	25'
M42	5h35m	–5°27'	4.0	65' by 60'
NGC 2237–9	6h32m	5°03'	—	80' by 60'
NGC 2264	6h41m	9°53'	3.9	20'
M41	6h46m	–20°45'	4.5	39'
NGC 2362	7h19m	–24°57'	3.8	6'
M46	7h42m	–14°49'	6.1	27'

Key: R.A. = Right ascension (2000.0); Dec. = Declination (2000.0); Mag. = Visual magnitude; Size is in arcminutes ('). 1' = 1/60°.

Start in Auriga

Let's begin with one of the finest open clusters in the sky: **M37**, also called the Salt and Pepper Cluster, in Auriga. From a dark site, sharp-eyed observers can see this cluster as a glowing spot without optical aid. Through binoculars, you'll also see M36 and M38, two other bright clusters 3.5° and 6°, respectively, to the northwest. But M37 is the one you want to concentrate on.

Through any size telescope, M37 displays an even stellar distribution not found in many other clusters. Although it sits squarely within the Milky Way, M37's edge is easy to discern.

A 3-inch scope reveals 50 stars. The brightest member — the magnitude 9.1 orange star HD 39183 — sits near the cluster's center.

With many open clusters, increasing the size of the telescope worsens the view; increased magnification causes a cluster's stars to thin. Also, larger scopes reveal more background stars, which makes it more difficult to see a cluster's outline. Not with M37. With this wonder, larger scopes reveal only more stars. Through a 10-inch scope, you'll count 200 stars, and a 16-inch will show 500.

On to Taurus

It's no great feat to spot the **Pleiades** (M45). You can see it from even a suburban site without optical aid. That's because this stellar group ranks as the sky's brightest star cluster.

The Pleiades (M45) is the sky's brightest star cluster. Easily visible to the naked eye, M45 explodes with stars through binoculars or a small telescope. George Greaney

Amateur astronomers with good vision from a dark site can spot more than the six stars most people see. My record is 11 Pleiads naked eye. How many can you see? Be sure the atmosphere is steady on the night you choose before you start counting.

Although M45 is a great naked-eye target, it also looks terrific through binoculars and small telescopes. Most amateur astronomers choose binoculars that magnify between 10 and 15 times to observe the Pleiades. If you use a telescope, low-power eyepieces work best.

To see the **Crab Nebula** (M1), however, you will need a telescope. Although the word "nebula" is part of this object's name, astronomers classify M1 as a supernova remnant.

The Salt and Pepper Cluster (M37) in Auriga the Charioteer glows brightly at magnitude 5.6. A 3-inch telescope will reveal 50 stars. Use a magnification around 100x. Anthony Ayiomamitis

M1 has high surface-brightness, so a 3-inch telescope (and even some binoculars) will reveal it. The object shines at magnitude 8.0 and has an oval shape oriented northwest to southeast.

The easiest way to find the Crab Nebula is to start at the blue magnitude 3.0 star Zeta (ζ) Tauri. From there, move a bit more than 1° to the northwest.

Move to Gemini

It's hard to resist a two-for-one sale, and that's exactly what our next wonder offers. **M35** lies 2.3° northwest of magnitude 3.3 Eta (η) Geminorum.

From a dark site, you'll spot this cluster easily without optical aid. Point a telescope at M35, however, and not only will it explode into stars, but you also will see a second open cluster, magnitude 8.6 NGC 2158. Use 100x or more.

M35 contains two dozen stars brighter than 9th magnitude, most of which lie near the cluster's center. In that region, look for a string of stars some 10' long shaped like a saxophone. The stars align in many other patterns; some of the arcs extend nearly 1°. Fainter members push the total number of visible stars past 200.

If you use a low-power eyepiece to observe M35, NGC 2158 will look like a small, fuzzy ball, so crank up the power. Note, however, that this cluster's stars don't resolve well through small scopes.

Next, the greatest nebula

No winter tour would be complete without a look at the **Orion Nebula** (M42), one of the sky's brightest diffuse nebulae. Easily seen from a dark site, sharp-eyed observers can detect this cloudy patch as the central "star" in Orion's Sword even under moderate light pollution.

Small telescopes don't quite show this object's full extent, which covers an area 6 times the size of the Full Moon. Use a magnification of 75x or more to explore the Trapezium, a group of recently formed stars in M42's heart.

Over to the Unicorn

It wouldn't surprise me if you haven't heard of the constellation Monoceros the Unicorn. It isn't bright, and Orion overshadows it. It does, however, contain two standout deep-sky objects, one of which is the **Rosette Nebula** (NGC 2237–9).

From a dark site, you'll first spot open cluster NGC 2244. A 4-inch telescope will reveal two dozen stars in an oval region elongated northwest to southeast.

To best observe the Rosette, use a magnification of 50x and attach a nebula filter to your eyepiece to dim NGC 2244's stars. The nebula's western side appears brighter. Here, the ring's inner wall appears straight with a bit of a ragged edge; the outer wall looks thin with an extension to the northwest.

The Rosette's eastern side is much wider. A nebulous wall with a well-defined border forms its northern edge.

Michael E. Bakich *is a senior editor of* Astronomy.

The Orion Nebula (M42) is one of the sky's brightest emission nebulae. Even a small telescope reveals contrasting regions of great detail. Adam Block/Mount Lemmon Sky Center/University of Arizona

The Rosette Nebula (NGC 2237–9) is a combination object that includes open cluster NGC 2244. The cluster lies in front of the Rosette's central dark region. Conrad Pope

The Christmas Tree Cluster (NGC 2264) sits in front of a vast region of bright gas and cold dust. Note the dark Cone Nebula to the right. Bob and Janice Fera

Although the Rosette is an emission nebula, your eye will also notice the many small dark nebulae superimposed on the bright background.

Monoceros' other highlight is the **Christmas Tree Cluster** (NGC 2264). At magnitude 3.9, this grouping of stars is easily bright enough to spot with your naked eyes from a dark site, albeit as an indistinct fuzzball.

At a magnification of 50x, you'll see a dozen or so stars to the east and west of the magnitude 4.7 star 15 Monocerotis. This line forms the 0.5°-long base of the Christmas tree. Its top points to the south. Although the southern stars form the tree's top, they're not members of this cluster, which lies approximately 2,500 light-years from Earth.

The Tau Canis Majoris Cluster (NGC 2362) sometimes gets overlooked by Northern Hemisphere observers, even though it's the sky's ninth-brightest open cluster. Most of the cluster's light comes from its namesake star. Tim Hunter

Continue to Canis Major

Next comes one of the easiest deep-sky targets because you can use the sky's brightest star as a guide to it. Open cluster **M41** lies 4° south of Sirius (Alpha [α] Canis Majoris). From a dark site, you'll easily spot M41 with your naked eyes.

Through a 6-inch telescope, you'll see about 50 stars. Star counts by astronomers indicate M41 contains about 100 member stars in an area slightly larger than that covered by the Full Moon.

At first glance, this cluster appears roughly circular. Closer inspection reveals several chains of stars running north-south.

Once you see the **Tau Canis Majoris Cluster** (NGC 2362) in Canis Major, you'll never mistake it for any other deep-sky object. The reason is the 4th-magnitude triple star Tau (τ) CMa located in the middle. No cluster star shines within 3 magnitudes of Tau.

To locate NGC 2362, find magnitude 1.8 Wezen (Delta [δ] Canis Majoris), and move 2.8° northeast. You'll spot the cluster easily with your naked eyes. Use binoculars, and you'll see that stars pack this area of the winter Milky Way.

Through a telescope, Tau dominates the view. In fact, it partially obscures many of the 10th-magnitude and fainter stars surrounding it.

To get an accurate count of the stars in NGC 2362, place Tau just outside the field of view, first to the north, then to each of the other three cardinal directions. Finally, simply count the suddenly visible fainter stars and add the four numbers together.

End in Puppis

The last winter deep-sky treat offers two targets in one. It's open cluster **M46**. The star cluster contains several hundred stars. You'll see 50 of them through a 4-inch telescope. The stars appear evenly distributed throughout a circle slightly less than 0.5° across.

Within M46's boundaries resides planetary nebula NGC 2438. It sits 7' north of the cluster's center and measures about 1' across. To see its doughnut-like shape through a small telescope, you'll need a dark site, steady air, and a magnification around 125x.

Now it's your turn to explore the winter Milky Way. Just bundle up, get out there, and give the objects on this list a try. You won't be disappointed.

See more images of these objects at www.Astronomy.com/toc.

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How to observe comets

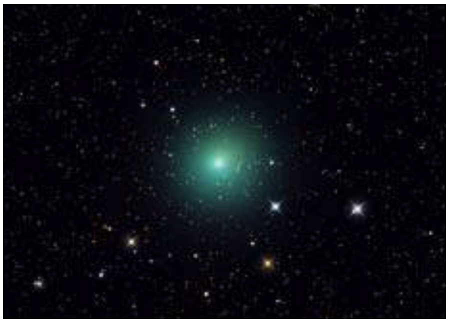
Nothing thrills skywatchers like a new comet, especially if it's bright. Follow these tips to be ready for the next one. **by Michael E. Bakich**

Many observers rate comets as their favorite observing targets. And why not? Most appear unannounced, seemingly out of nowhere. Some shine brightly. A few rise to a spectacular level. Amateur astronomers live for events like that.

Unfortunately, we haven't had many bright comets lately. Still, the next one could lie right around the corner.

Comets are small, irregularly shaped bodies made up of dust grains and frozen gases. Many travel along elliptical orbits that occasionally bring them close to the Sun and then take them deep into space, far beyond Pluto's orbit.

Comets develop a surrounding cloud of thinly distributed material, called a coma, that grows in size and brightness as the comet approaches the Sun. A small nucleus, usually less than 6 miles (10 kilometers) across, remains hidden within the coma.

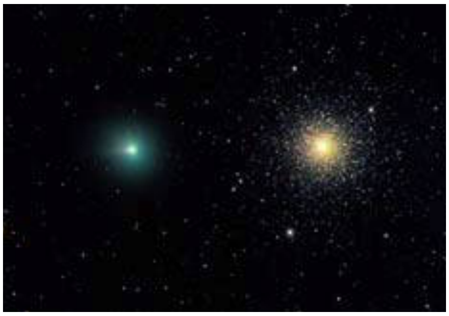


Comet C/2007 W1 (Boattini) exhibited a large coma and a high degree of condensation May 6, 2008. The imager used a 10-inch ASA Astrograph at f/3.8 and a Finger Lakes Instrumentation Microline 8300 CCD camera. His image totaled 16 minutes of exposure time. Gerald Rhemann

When far from the Sun, the gas in the nucleus is frozen solid. During that time, the comet appears faint, and we see only sunlight reflected off of the nucleus. When a coma develops, released dust reflects more sunlight, and gas in the coma absorbs ultraviolet radiation and begins to fluoresce. At about 5 astronomical units (one AU is the average Earth-Sun distance) from the Sun, fluorescence contributes more to the comet's brightness than reflected light.

As comets approach the Sun, they develop tails of luminous material that extend from the heads. Some of these tails are enormous, stretching for tens of millions of miles. The solar wind accelerates material away from a comet at different velocities depending on the size and mass of the particles. This can create two types of tails — dust and ion. A dust tail contains some mass, so it accelerates slowly and tends to curve. An ion tail (composed of charged gases) is much less massive, so it accelerates in a nearly straight line extending opposite the Sun.

Michael E. Bakich *is a senior editor of* Astronomy.



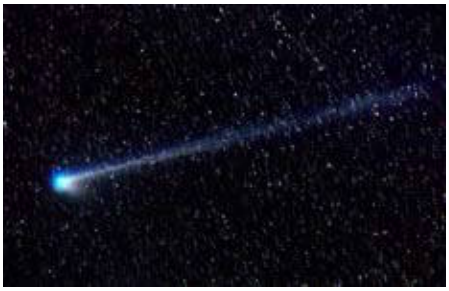
Comet C/2006 VZ13 (LINEAR) passed near globular cluster M3 in Canes Venatici July 24, 2007. The comet's large coma, bright center, and green color were easily visible through small telescopes. Michael Jäger and Gerald Rhemann

Observing bright comets

Comets reward the patient observer. If you can see a comet without optical aid, certain questions will help you make a detailed observation. What is the comet's altitude? In which constellation(s) does it lie? If you're observing from a dark site, does the target lie against the background of the Milky Way?

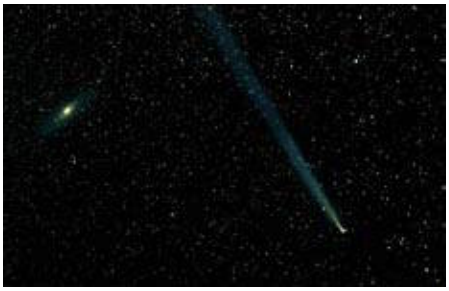
Next, note the coma's apparent size. Try to determine the full extent of the tail and its width both near the coma and at the end. Can you see both a dust tail and an ion tail? How do they differ? Finally, note the color of all parts of the comet, especially the tail. If you choose to sketch the comet, be sure to note the date, time, and the direction north on your drawing.

For most bright comets, binoculars provide the best views. Binoculars offer some magnification, darken the sky

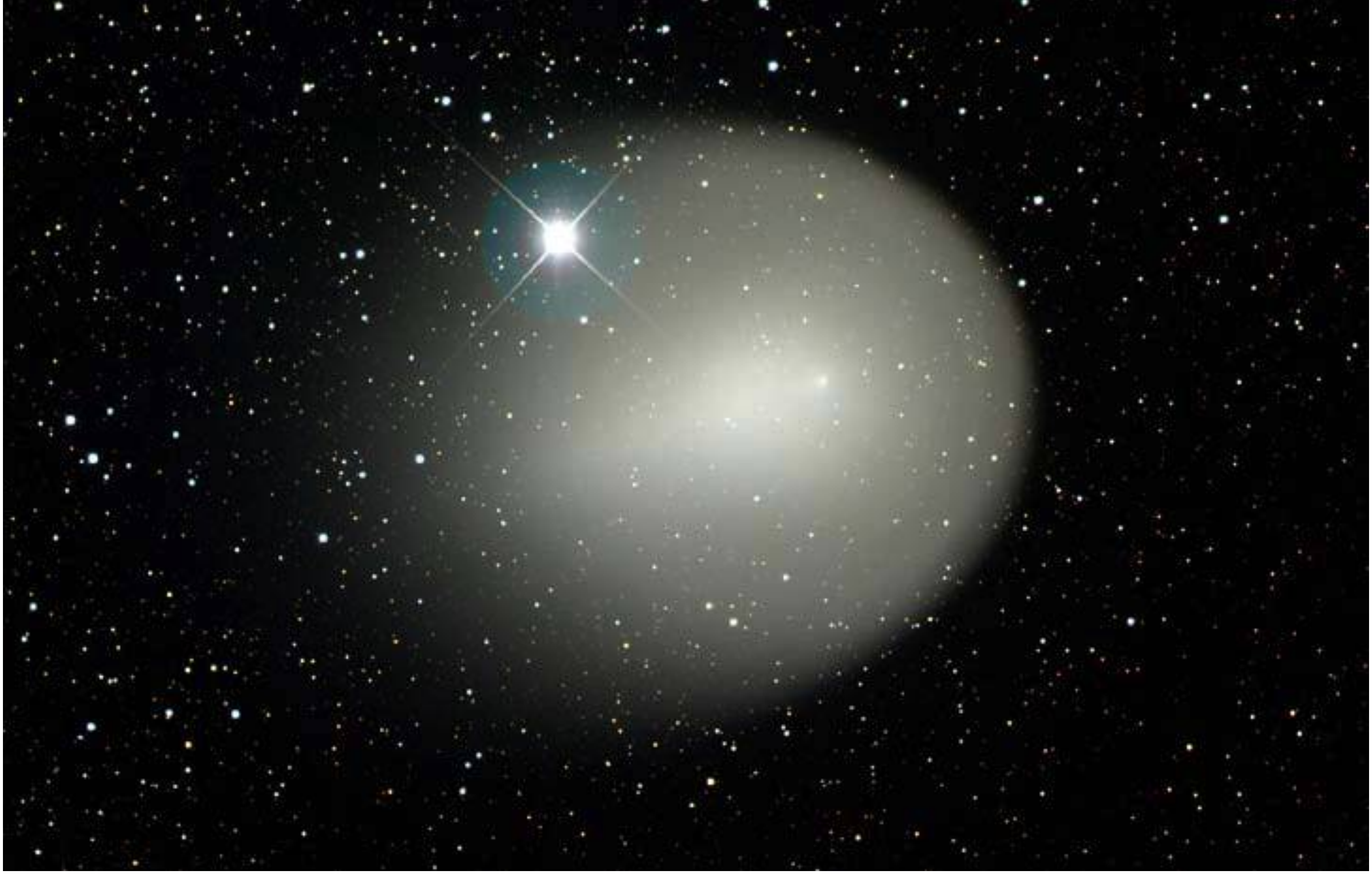


Comet C/2006 A1 (Pojmanski) displayed two colorful tails March 8, 2006. The ion tail (made of charged gases) shone with a blue color. The shorter yellowish dust tail appeared thicker and points to the lower right in this image. The comet's coma shone mostly blue. Paolo Candy

Comet C/2004 F4 (Bradfield) was bright enough to spot in the east-northeast during morning twilight April 25, 2004. At the time of this exposure, the comet was leaving the inner solar system. C/2004 F4 was Australian comet-hunter William Bradfield's 18th discovery. Tom Polakis



Comet C/2004 F4 (Bradfield) drifted by the Andromeda Galaxy (M31) May 1, 2004. The imager connected a 50mm f/2.8 lens to an SBIG ST-2000XM CCD camera and created an LRGB image with exposures of 16, 4, 4, and 4 minutes, respectively. Dean Salman



Comet 17P/Holmes' coma engulfed magnitude 1.8 Mirfak (Alpha [α] Persei) November 19, 2007. The imager captured 20 one-minute exposures (five each through red, green, and blue filters, plus five without a filter) with a Santa Barbara Instrument Group ST-2000XM CCD camera attached to a 7.2-inch Takahashi Epsilon 180 astrograph. 17P/Holmes was a long-lived naked-eye comet that thrilled Northern Hemisphere observers. Brian Kimball

background a little, and provide a wide field of view. Through binoculars, observe how much farther from the comet's head you can see the last wisps of the tail. If both types of tail are visible, note any increased definition in either and any colors (compared to your naked-eye view). Also note the separation and shapes of the two tails.

Degree of condensation

One detail to note as you observe a comet is its degree of condensation (DC). This indicates how much the surface brightness of the coma increases toward its center. As the DC increases, the coma size usually decreases, and the coma appears more defined.

Astronomers assign a DC of 0 to a totally diffuse comet with no brightening toward the center. Between DC 3 and 5, the coma's center appears distinctly brighter. By DC 7, the comet exhibits a steep overall gradient, and at DC 8, the coma appears small and dense with well-defined boundaries. At DC 9, the comet looks like a fuzzy star or a planet viewed in bad seeing.

Comet C/2008 T2 (Cardinal) mingled with the stars of open cluster M38 in the constellation Auriga April 14, 2009. The smaller open cluster near the top of the image is NGC 1907. M38 measures 15' across. The coma shone blue, but the comet had no tail. Brian Kimball

Comet 144P/Kushida (arrow) appeared a deep shade of green in the center of the Hyades star cluster in Taurus February 2, 2009. The brightest star is magnitude 0.9 Aldebaran (Alpha [α] Tauri), and the small open star cluster to the upper left is magnitude 6.4 NGC 1647. Chris Schur

The top 24 recent comets

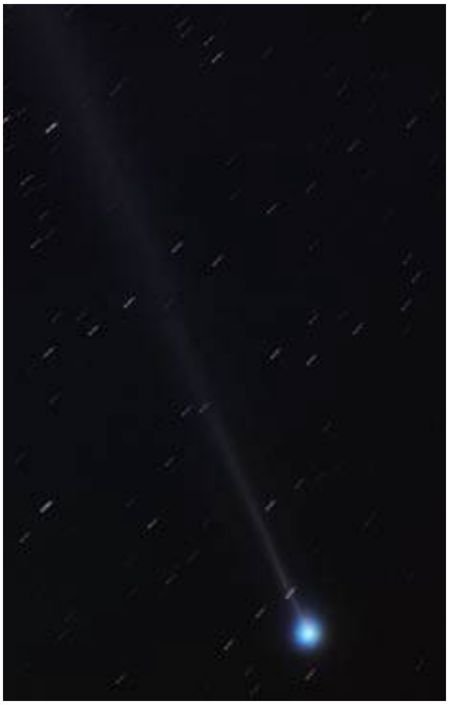
This table lists the brightest 24 comets, in order of apparent visual magnitude, observed by ground-based observers since 1965.

C/1965 S1 (Ikeya-Seki)	–10.0
C/2006 P1 (McNaught)	–5.5
C/1975 V1 (West)	–3.0
C/1995 O1 (Hale-Bopp)	–0.8
C/2002 V1 (NEAT)	–0.5
C/1996 B2 (Hyakutake)	0.0
C/1969 Y1 (Bennett)	0.0
C/1973 E1 (Kohoutek)	0.0
C/1998 J1 (SOHO)	0.5
C/1970 K1 (White-Ortiz-Bolelli)	1.0
C/1983 H1 (IRAS-Araki-Alcock)	1.7
C/2002 T7 (LINEAR)	2.2
1P/1982 U1 (Halley)	2.4
17P/2007 (Holmes)	2.4
C/2000 WM1 (LINEAR)	2.5
C/1964 N1 (Ikeya)	2.7
C/2001 Q4 (NEAT)	2.8
C/1989 W1 (Aarseth-Brewington)	2.8
C/1963 A1 (Ikeya)	2.8
C/2002 C1 (Ikeya-Zhang)	2.9
C/2001 A2 (LINEAR)	3.0
C/2004 F4 (Bradfield)	3.3
C/2004 Q2 (Machholz)	3.5
C/1980 Y1 (Bradfield)	3.5

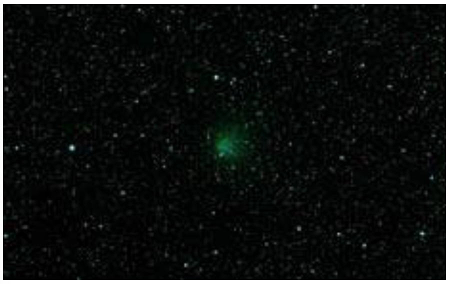
Comet-shooting tips

If a bright comet is visible, get out your camera and shoot! You may be surprised by what you record. And in today's digital age, once you have a camera it costs nothing to shoot lots of images. Try all your camera's settings, then save the good pictures, and toss the ones you don't like. Here are a few more tips:

- Mount your camera on a tripod for maximum stability.
- Always use a cable release. By not touching your camera, you limit vibrations that can ruin an image.
- If your camera has a "manual" setting, use it. For tripod-mounted shots, choose a fast ISO setting, and bracket your exposures. Bracketing is a technique where photographers choose a range of lens openings (f stops) or shutter speeds during a sequence of exposures.
- If you have more than one lens, use them all. If any have a zoom capability, try changing that setting from one exposure to the next in a series of shots.
- Take the surroundings into account. Some of the most pleasing shots of comets show foreground objects such as buildings, an observer, or even a body of water that reflects the comet's image.
- For piggyback shots where you connect a camera to a motor-driven telescope, try a slower ISO setting, which will produce less electronic noise. This may allow you to record better detail.
- Plan to record more of the comet's tail than you can see with your naked eye. Frame the comet appropriately. — *M.E.B.*



Comet C/2007 F1 (LONEOS) reached perihelion (closest approach to the Sun) October 28, 2007, 2 weeks after Rhemann recorded this image. Astronomers discovered the comet March 19, 2007, as part as the Lowell Observatory Near Earth Object Search (LONEOS). Gerald Rhemann



Comet 2P/Encke has the shortest period of any comet. It orbits the Sun once every 3.3 years. This image, taken November 17, 2003, shows the comet's intense green color and diffuse nature. Mike Holloway

Estimating magnitude

One mistake some amateur astronomers make is to underestimate the coma's total brightness. They concentrate too much on the stellar central portion. Also, from an urban setting the outer coma is often lost because of light pollution.

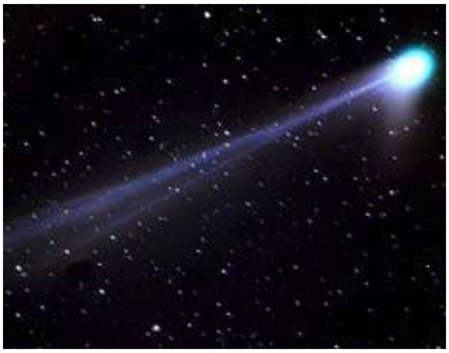
To estimate a comet's visual magnitude through binoculars (or a telescope for smaller and fainter comets), defocus the images of nearby stars to the same size as the normal in-focus view of the comet's coma, then compare the brightnesses. This technique works better for diffuse comets. A comet with a high DC usually has a large brightness difference between the outer coma and the central region. That makes comparing it with out-of-focus stars difficult because the stars' images appear more uniform.

Observing faint comets

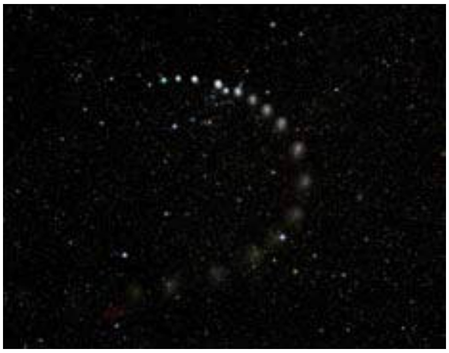
You'll be able to find and follow most comets through a 6-inch telescope from a dark observing site. Because comets are extended objects (not point-sources), light pollution hampers their visibility to a much greater degree than it does planets or star clusters. If you must observe a comet from suburbia, a 10-inch telescope is about the smallest instrument you should use. Most amateur astronomers' telescopes can detect comets when they shine between 10th and 11th magnitude, similar to the faintest galaxies on Charles Messier's list.

Hopefully, the comet will peak in brightness when the Moon is out of the sky. Even that natural form of light pollution hides the outer coma and makes low-contrast features difficult to see. The

Comet C/2007 N3 (Lulin) reached its peak brightness February 24, 2009. Most comets carry the names of the observers who find them, but astronomers christened C/2007 N3 after Lulin Observatory in Taiwan, where one of its discoverers took the first image of it. Phillip L. Jones



Comet C/2001 Q4 (NEAT) passed closest to Earth May 6, 2004, and closest to the Sun May 15. This image, taken June 6, shows incredible structure in the comet's long, graceful tail. Note the stubby, yellowish dust tail projecting downward from the comet's head. Paolo Candy



Comet 17P/Holmes' position and appearance changed a lot. This image combines 19 exposures from October 25, 2007, to March 27, 2008. The imager changed the exposures and ISO settings from night to night according to sky conditions and the presence of moonlight. Tunç Tezel week on either side of Full Moon usually belongs to CCD imagers rather than to visual observers. That's because photographers can electronically subtract the extra sky light from the image.

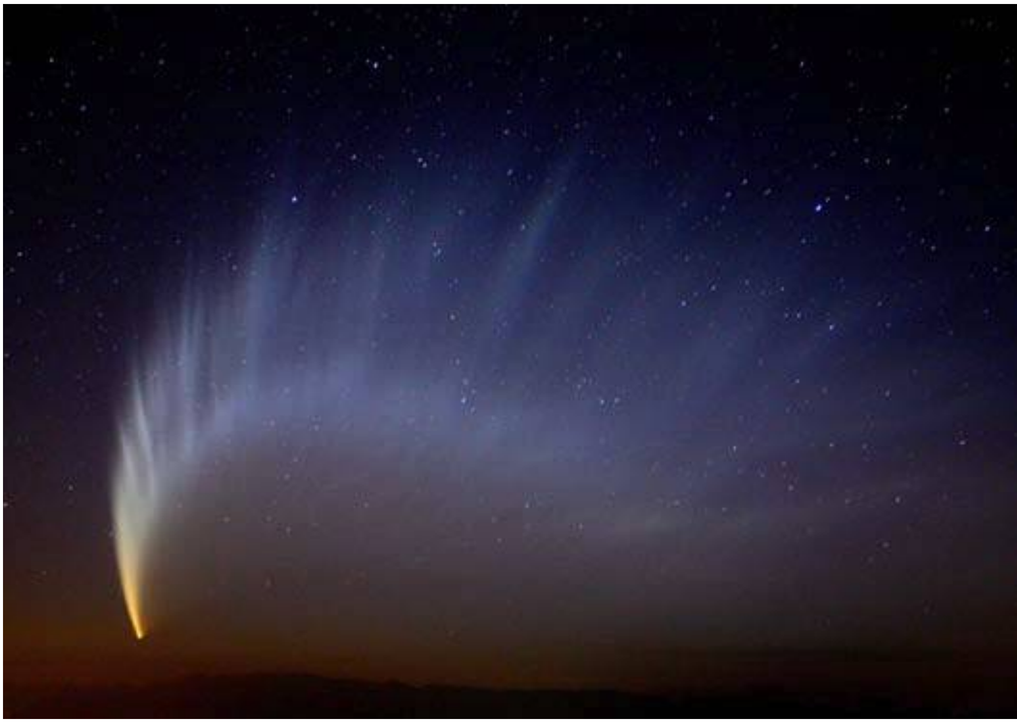
Even from a country location, the background sky can be bright enough at low power to hide the faint, fuzzy glow of the comet. Nudge the power up to 100x or more to increase the contrast between the comet and the background sky. Try using a dark cloth or towel to cover your head and the eyepiece. By eliminating as much stray light as possible, you can see faint details more easily. On cooler evenings, try not to fog the eyepiece with your breath.

A telescopic observation will allow you to examine the coma in detail. Use a variety of magnifications, and take your time. Although high magnification will darken the field of view, your eye is better at detecting faint structure when it's bigger. Slowly move your eye around, and focus on high-contrast zones.

Does the coma look elliptical (and to what degree) at all magnifications? Note any irregularity in its shape or brightness. On many occasions, even observers using medium-sized telescopes have seen fragmenting within the coma. If you're lucky enough to see this, the comet will appear to have several bright central regions.

When observing at high power, also look for jets. These features will appear as lines or rays generally in the Sun's direction because outgassing from heating on the comet's sunward side creates them.

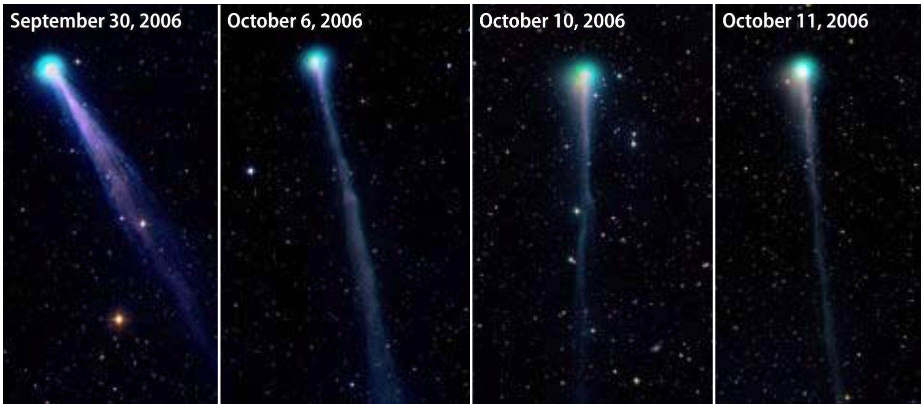
Find out how to determine atmospheric extinction at www.Astronomy.com/toc.



Comet C/2006 P1 (McNaught) displayed a magnificent curving dust tail January 21, 2007. Comet McNaught attained magnitude –5.5, making it the second-brightest comet in more than 80 years. Unfortunately, few Northern Hemisphere observers saw this southerly comet at its grandest. Richard Simon

Comet C/2004 Q2 (Machholz) passed reflection nebula NGC 1333 in Perseus January 11, 2005. The nebula lies 720 light-years from Earth, more than 37 million times farther than the comet on the date of this image. Michael Jäger and Gerald Rhemann

The California Nebula (NGC 1499) was next in line for Comet C/2004 Q2 (Machholz), and the two objects offered astroimagers a dramatic color contrast. The comet passed this deep-sky object January 13, 2005. Michael Jäger and Gerald Rhemann



September 30, 2006

October 6, 2006

October 10, 2006

October 11, 2006

Michael Jäger and Gerald Rhemann

Comet C/2006 M4 (SWAN) appeared different (especially the structure of its tail) every night from September 30 to October 11, 2006. Rob Matson of Irvine, California, and Michael Mattiazzo of Adelaide, South Australia, discovered this comet on publicly available images taken by the Solar Wind ANisotropies (SWAN) instrument aboard the Solar and Heliospheric Observatory spacecraft.

Comet C/2007 E2 (Lovejoy) appeared green and highly diffuse, sporting a faint tail measuring about 45' long May 11, 2007. Comet Lovejoy was not bright enough to see without optical aid, but binoculars brought it into view. John Chumack

Celestron revives a classic scope

With the Omni XLT 127, Celestron has made its signature 5-inch scope even better. **by Raymond Shubinski**

Celestron is famous for its high-quality Schmidt-Cassegrain telescopes. Anyone who has attended a large star party has seen a variety of these scopes. Now Celestron has updated one of its all-time favorites — what had been the company's traditional 5-inch telescope — as the Omni XLT 127.

For this new incarnation, Celestron replaced the old orange-and-black finishes with a deep metallic-blue barrel and powder-coated white end caps. The XLT 127 comes with a German equatorial mount, slow-motion controls, and a high-quality stainless steel tripod. The package also includes a 25mm eyepiece and a 1¼" star diagonal.

Out of the box

I found setting up this scope easy. The equatorial mount, however, may baffle some first-time telescope owners. Fortunately, the XLT 127 comes with a detailed manual. I strongly suggest that newcomers to observing (and even old hands) read the instructions.

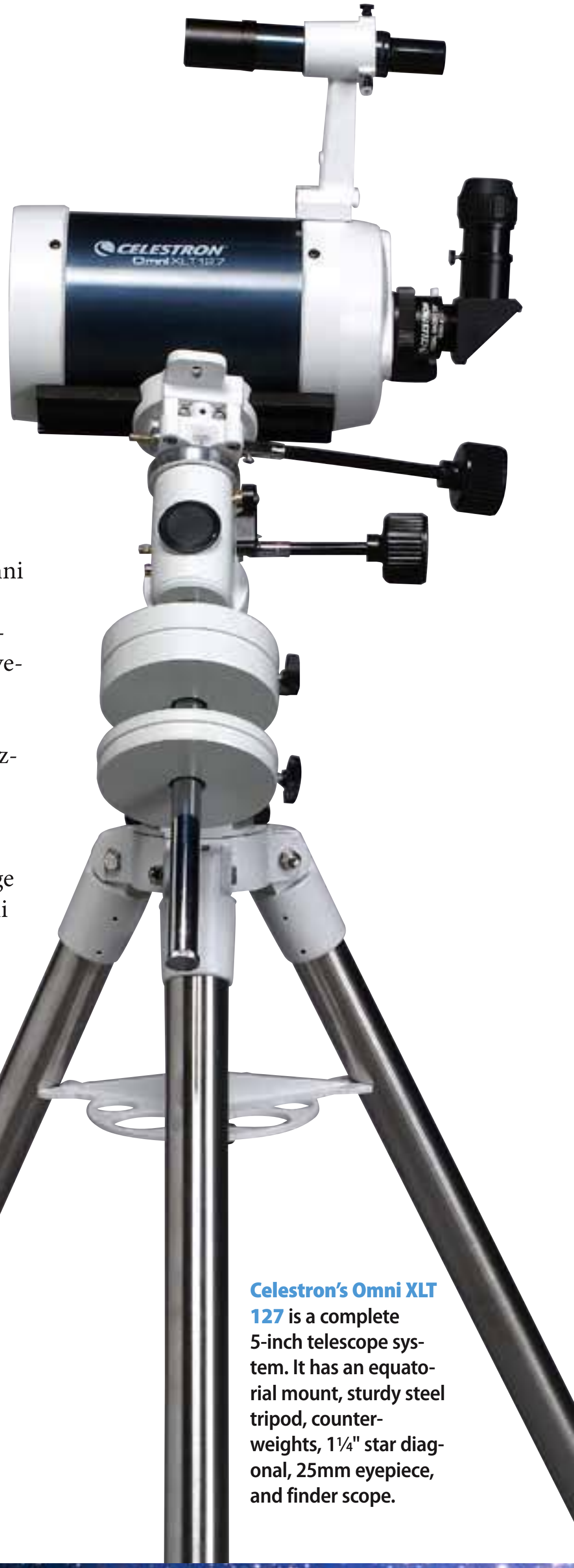
Two problems most users have with a German mount is balancing the scope and lining it up with the North Celestial Pole. You'll find detailed answers to both issues in the information supplied and at Celestron's web site (www.celestron.com). The Omni XLT 127 also comes with a level-one copy of *TheSky* software. This nice add-on will prove helpful for planning an evening of observing.

Five inches (127mm) of aperture means this telescope is for casual skygazing. With its 1250mm focal length, inserting the 25mm eyepiece gives a comfortable magnification of 50. You'll want to add other eyepieces with a range of focal lengths to fully utilize the Omni XLT's potential.

The XLT 127 is mechanically stable. The focus is smooth, and the right ascension and declination motions have little or no backlash. The mount has ball bearings in both axes to aid in its smooth motion. The steel tripod is also steady. I noticed almost no vibration despite the unit's light weight.

I would recommend using a larger finder scope than the one provided. The 6x30 finder scope sits away from the main

The optics of the Omni XLT 127 are Schmidt-Cassegrain. Celestron added its StarBright coatings to enhance image contrast. The optical tube has a focal length of 1,250 millimeters and a focal ratio of f/9.84.



Celestron's Omni XLT 127 is a complete 5-inch telescope system. It has an equatorial mount, sturdy steel tripod, counterweights, 1¼" star diagonal, 25mm eyepiece, and finder scope.

Specifications

Omni XLT 127

Optical design: Schmidt-Cassegrain
Aperture: 5 inches (127mm)
Focal length: 1,250mm
Focal ratio: f/9.84
Mount: Omni CG-4 equatorial
Optical tube length: 11 inches (279mm)
Optical tube weight: 6.5 pounds (3 kilograms)
Equatorial mount weight: 21 pounds (9.5 kg)
Tripod weight: 12.5 pounds (5.7 kg)
Also includes: 6x30 finder scope, 1¼" star diagonal, 25mm eyepiece (50x), counterweights, slow-motion cables
Price: $659

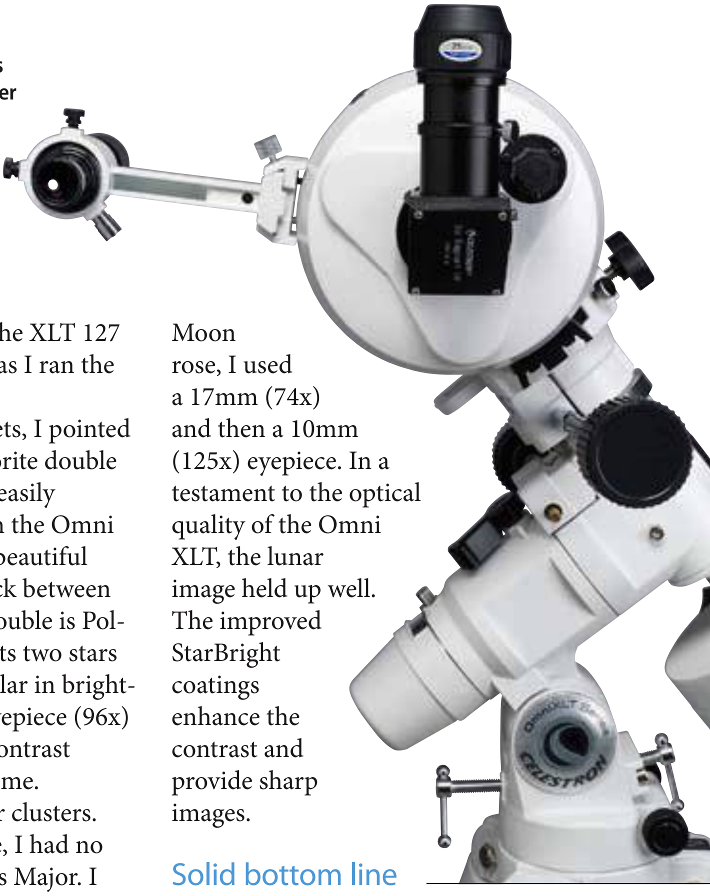
tube's body, but with only a 30mm aperture, faint objects are hard to see.

The Omni XLT 127 is not a computer-driven scope. However, a number of upgrades are available. One of the most useful is the dual-axis motor drive, which allows for tracking in right ascension and adjustments in declination.

Sky-testing the scope

Observing on a clear winter night in southern Nevada has some real advantages, such as the moderate temperature and lack of atmospheric aerosols. The one major disadvantage, however, is the serious light pollution. Despite that, the XLT 127 performed well.

To check for any problems with spherical aberration, I used a short-focal-length eyepiece. If I collimated the scope well, a defocused medium-bright star should show a nice "target" pattern of light rings with distinct dark areas between the bright circles. The XLT 127 showed perfect sets of rings as I ran the focus inward and outward.



The rear of the telescope accepts the star diagonal. The single focuser knob lies just to its upper right in this picture. A metal arm holds the 6x30 finder scope at a comfortable distance from the main tube. Equipment photos: *Astronomy*: William Zuback

For my first celestial targets, I pointed the scope at some of my favorite double stars. Delta (δ) Orionis split easily through the 25mm. Through the Omni XLT, each of the stars was a beautiful stark white with distinct black between them. A more challenging double is Pollux (Beta [β] Geminorum). Its two stars lie only 5" apart and are similar in brightness. I had to use a 13mm eyepiece (96x) to split the pair. Again, the contrast between the stars impressed me.

I then moved to a few star clusters. Through the 25mm eyepiece, I had no trouble finding M41 in Canis Major. I could see a lovely yellowish-red star near the center of the cluster, which gives a nice contrast to the field of stars.

M35, which lies near the foot of the twin Castor, was another marvelous object even with all of the sky glow. The cluster was easy to find with low power and spread out in the field of view. Finally, I turned the XLT 127 on the Beehive Cluster (M44) in Cancer. Switching to a 36mm eyepiece (35x) allowed me to sweep up the entire cluster at once.

Saving the best for last, I turned the scope toward the Orion Nebula (M42). Using Celestron's 25mm eyepiece, I let M42 drift into the field of view. As it moved into the field, I could see the "winglike" filaments spreading out from the central area of the nebula. The famous Trapezium of stars near the nebula's center was easy to spot. Later, as the Moon rose, I used a 17mm (74x) and then a 10mm (125x) eyepiece. In a testament to the optical quality of the Omni XLT, the lunar image held up well. The improved StarBright coatings enhance the contrast and provide sharp images.

Solid bottom line

I found the Omni XLT 127 to be a high-quality and easily transportable telescope to take in search of dark skies. With a barrel length of only 11 inches (279mm), the optical tube assembly fits nicely into a small duffle bag. You can disassemble the tripod and place it on the backseat of your car. The 5-inch Celestron has been a favorite among amateur astronomers since its introduction in 1971. The newest version is a great upgrade of an old standard.

Raymond Shubinski *is a contributing editor of* Astronomy *who observes from Henderson, Nevada. He loves telescopes.*

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Evening Stars

by David H. Levy

Amateur outreach

Two members of the Tucson Amateur Astronomy Association personify what the International Year of Astronomy means.

The more I think about it, the more I am convinced the International Year of Astronomy (IYA) is meant for the world's amateur astronomers. Even its goal — to show the world that the universe is "yours to discover" — is designed to inspire people unfamiliar with astronomy to take their first looks skyward.

Encouraging others to observe the heavens is a magic prescription, and those best qualified to follow it through are amateur astronomers. Two inspiring stargazers in my community are Teresa Lappin, who recently completed more than 2 decades as treasurer of the Tucson Amateur Astronomy Association (TAAA), and Gary Rosenbaum, a TAAA member who has studied Mars faithfully for many years.

Terri has shared her own enthusiasm for astronomy since the late 1970s, when she joined our local astronomy club. Almost singlehandedly, she persuaded the TAAA to participate in the Astronomical Society of the Pacific's Night Sky Network, a program designed to provide beginners with simple tools and activities that encourage their interest in astronomy. Terri overcame objections from some TAAA members who considered themselves too advanced for this sort of thing.

Gary Rosenbaum shows his expertise cleaning the Vatican Advanced Technology Telescope (VATT) primary mirror. David Harvey Photography

Now the organization conducts many activities for people to look through telescopes. It invites others to see Saturn's exquisite ring system or to follow the motions of Jupiter's four bright moons. It encourages beginners to enjoy the changing phases of the Moon and watch as each night reveals new craters or mountain peaks previously invisible. Every look through a small telescope brings discoveries to enrich the mind.

Gary Rosenbaum's story is different. When I first met him in the early 1980s, he was starting a small telescope business called The Image Point. It featured telescopes containing some of the best optics I had ever seen or used. Countless people would enter his Swan Avenue shop in Tucson to marvel at the quality of Gary's 14-inch reflectors on ultra-heavy-duty mounts. His telescopes were just about the best you could get in the pre-go-to era. He even offered a 6-inch version for beginners that I have often recommended.

After a few years, I sensed that Gary was starting to tire of the responsibility of managing his own business, especially one that specialized in a few handmade telescopes. After he closed The Image Point, Gary earned a position at the Steward Observatory to assist with its family of telescopes on Mount Lemmon and Mount Bigelow, as well as atop Kitt Peak. Gary's job is partly maintenance, to keep the telescopes in top shape for the many University of Arizona observers who depend on them.

Terri Lappin (in green) shares her enthusiasm about the Sun with a group of visitors at a recent Sharing the Sky Star Night. Wendee Wallach-Levy

Gary's personality changes to an intense focus on the task at hand whenever Mars — his first love — makes its biannual approach to Earth. As it appears bright in our night sky, he concentrates fully on studying the planet's intricate surface details. Whether as business owner or an observatory employee, Gary has never lost his passion for the Red Planet.

Aside from his time observing Mars, Gary rarely hesitates to join Terri whenever an astronomy activity for youngsters occurs. Both Gary and Terri have helped with the public star nights organized by the Sharing the Sky Foundation. Last year, for example, Terri set up a table crowded with astronomy experiments designed for children.

These two amateur astronomers personify what the IYA is all about. But with such an emphasis on astronomy outreach, one might think the IYA is meant only to turn beginners on to the sky. It is. But we are all beginners. Whether we are truly just starting out or we know every star in the sky as an old friend, each clear night is a new beginning. Yes, the next clear night is amateur hour — not in the sense that we don't know what we're doing, but in the original Latin *amatorem*, meaning a lover. We choose to look at the sky, like Terri and Gary, because we love to do so.

Browse the "Evening Stars" archive at www.Astronomy.com/Levy.

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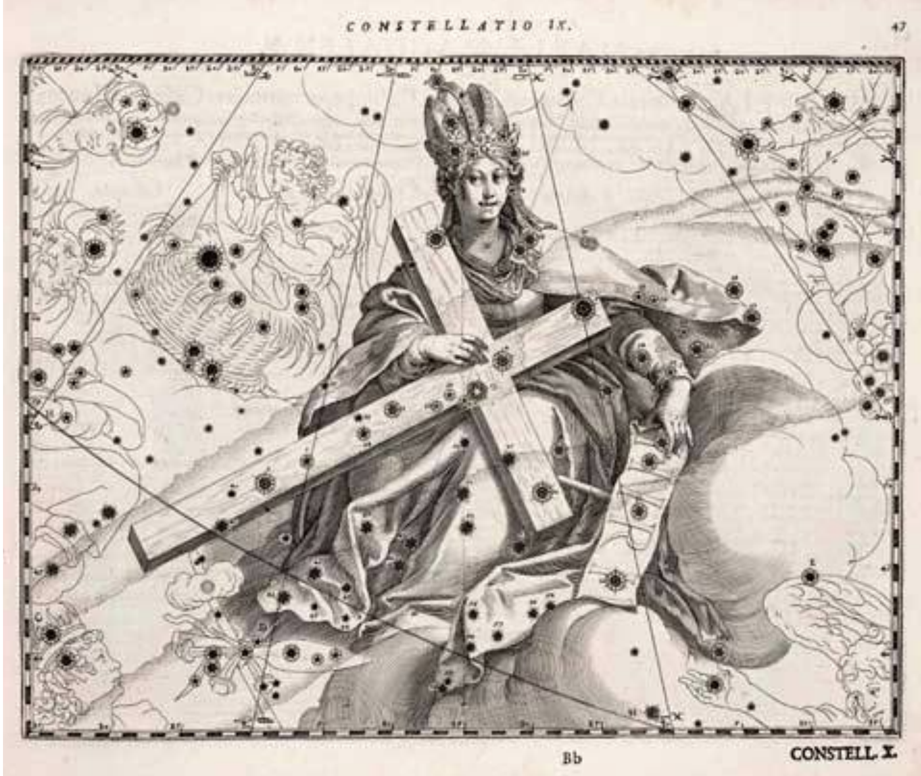
The Christmas Cross: a matter of life and death

The Northern Cross sets in the west-northwest as Christians celebrate Jesus' birth.


CONSTELLATIO IX.
47
Bb
CONSTELL. X.

Julius Schiller's 1627 star atlas, *Coelum Stellatum Christianum* ("Christian Starry Heavens"), shows Cygnus as St. Helen holding the cross of Calvary (our Northern Cross). Schiller created his atlas in the old style, so the sky appears flipped, as if you were outside the starry heavens looking down on them. The astute may notice an extra star (labeled "G" on the chart near Gamma Cygni [labeled "4"]). This is the exotic variable star P Cygni, which rose to 3rd magnitude in 1600 and was believed to be a "new star." Linda Hall Library of Science, Engineering, and Technology

As Christmas nears, go outside around 8 P.M. and look for a large, striking crucifix of stars standing right above the west-northwest horizon. It is a sight to behold and a powerful symbol to ponder.

Known today as the Northern Cross, this roughly 20°-long asterism is made up of the brightest stars in the constellation Cygnus the Swan: Deneb (Alpha [α] Cygni) marks the tip of the Cross; Albireo (Beta [β] Cygni) lies at its foot; and Epsilon (ε), Gamma (γ), and Delta (δ) Cygni form the crossbeam.

The Northern Cross is not one of today's constellations, although its form is arguably more recognized than its official figure. This certainly was the case in the 17th century when certain sects of skywatchers bestowed religious significance upon the star pattern. While to many these stars formed the outline of a celestial bird (including a swan, horned owl, or ibis), others saw them as Christ's cross. German lawyer Julius Schiller (c. 1560–1627), for instance, transformed Cygnus into St. Helen holding the cross of Calvary (the stars of the Northern Cross) and depicted them as such in his 1627 star atlas *Coelum Stellatum Christianum* ("Christian Starry Heavens"). Today's Northern Cross descended from these pious portrayals.

Actually, Schiller did more than glorify the stars of the cross. He gave Scripture names to all the constellations in the heavens, renaming the zodiacal constellations after the 12 apostles, the northern constellations after figures from the New Testament, and the southern constellations after figures from the Old Testament.

Centuries ago, publishing one's personalized view of the heavens was commonplace. As Garrett P. Serviss wrote in his 1910 book, *Round the Year with the Stars: The Chief Beauties of the Starry Heavens as Seen with the Naked Eye*: "The constellations have been reshaped many times in the past. The 'geography of the heavens' has known as many changes as that of the earth, the ambition of the old astronomers being sometimes as insatiable as that of founders of terrestrial kingdoms and empires."

Browse the "Secret Sky" archive at www.Astronomy.com/OMeara.

A matter of life and death

While the upright position of the Northern Cross (as seen from the Northern Hemisphere around Christmastime) is interesting, so too is its placement close to the western horizon shortly after sunset.

The stars, like the Sun, are born (rise) in the east and die (set) in the west. The irony is that as Christians celebrate the birth of their savior each December 25, the cross of Calvary stands boldly before them in the western sky at night. You don't need much imagination to see it as a cemetery cross lancing the Earth, metaphorically placing the body of Christ at death's door at the time of his birth.

But consider the unspoken message of the Latin cross, which the stars of the

The Northern Cross is a roughly 20°-long asterism made up of the brightest stars in the constellation Cygnus the Swan. Its form lies atop the Great Rift, a series of overlapping non-luminous molecular dust clouds located between the solar system and the Sagittarius Arm of the Milky Way. To the naked eye, they divide the bright band of the Milky Way lengthwise through Cygnus. John Chumack

Northern Cross best represent. Over the years, the Latin cross has evolved to stand for both death and rebirth, reflecting the belief that Christ's dying on the cross gave him eternal life.

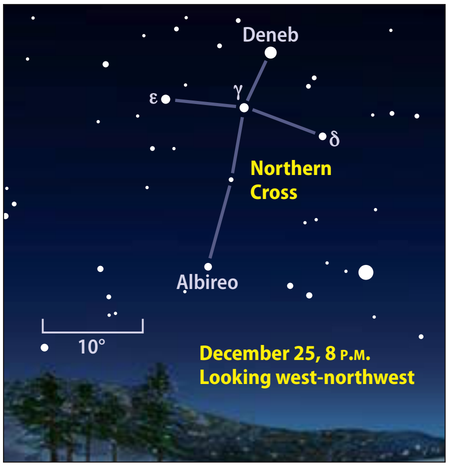
The imagery is strikingly similar to that associated with the ancient Egyptian cross, the *ankh*. Although scholars still debate the ankh's form, many widely accept it as a hieroglyphic character for life. Several scholars have proposed that the ankh's vertical axis represents the life-sustaining waters of the Nile, while the crossbeam shows the eternal journey of the Sun over it, from east to west. They also suspect that the ankh's top loop represents the Sun on the horizon — a symbol of the Sun's eternal life, crossing over each day from death in the west to rebirth in the east.

A dark baptism

If the Latin cross is a modified ankh, then it's easy to imagine the Northern Cross as that ancient symbol, with brilliant Deneb representing the Sun, the crossbeam the horizon, and the long axis the sacred Nile. Those under a dark sky can also see a celestial river (the Milky Way) following the long axis of the Cross.

Curiously, in the New Testament, St. Matthew tells us that at Christ's crucifixion, darkness fell over the land. Then, at the moment of his death, "the veil of the temple was rent in twain from the top to the bottom" (Matthew 27:51).

The veil of the sky temple (the Milky Way) on which the Northern Cross projects is, in fact, split in two. Known today as the Great Rift, this dark cloud separates the stream of the galaxy lengthwise through Cygnus, where it divides and fans into a delta of darkness. In December, these dark waters seem to pour down from the sky and baptize the land. To quote Romans 6:3: "Know ye not, that so many of us as were baptized into Jesus Christ were baptized into his death?"



December 25, 8 P.M.
Looking west-northwest

Around Christmas, the Northern Cross stands tall right above the west-northwest horizon at about 8 P.M. local time. *Astronomy*: Richard Talcott and Jay Smith

Arguably, Schiller recognized these cosmic coincidences and took them into consideration when he created his atlas. He shows the cross of Calvary with the Great Rift; he places the manger (Lyra) adjacent to the cross; he even depicts Hercules as the three wise men. (The atlas was created in the old style, so the sky appears flipped, as if you were outside the starry heavens looking down on them.)

Rebirth

With the Northern Cross standing at death's door as Christmas nears, is there anything rising in the eastern sky symbolic of hope or rebirth? In December 1987, Jack Horkheimer, Miami Space Transit Planetarium director and the host of TV's *Star Gazer*, came up with the answer. Yes!

While researching his Christmas show, Horkheimer recalled that the open star cluster M44, commonly known as the Beehive, originally was called the "Praesepe." This is Latin for "manger," in deference to the straw-filled manger in which the infant Jesus was born. Indeed, the word *praesepe* is derived from *praesepire* ("to enclose"), the root word of which is *presepio* ("nativity scene").

Curious, Horkheimer picked up a star wheel, dialed in December 25 at 8 P.M., and "noticed something which gave me a pleasant start." At this date and time, M44 is directly opposite the Northern Cross, just rising (being born) in the eastern sky.

"How poetic," Horkheimer said in his Christmas show. "In all my years as a star gazer, I had never heard or read of this lovely coincidence. So, as you gaze up at the night sky this Christmas week at the setting Cross and the rising Manger, may the heavens themselves remind you of a wish that should know no religious boundaries and that is simply: Peace On Earth, Good Will Toward Men … a hope for all mankind of all beliefs if we remind each other to keep looking up!"

NEXT MONTH
in the January issue

Springel et al. (2005)

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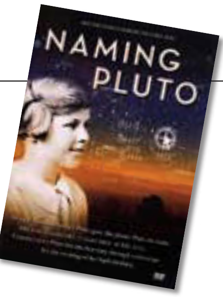

Naming Pluto introduces viewers to Venetia Burney Phair, the person who, at age 11, suggested the name Pluto for the solar system object discovered in 1930. The film runs 13 minutes, and both PAL and NTSC versions are available.

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82° eyepiece

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Watsonville, California

Orion's 7mm MegaView Ultra-Wide Eyepiece boasts an 18.5mm ocular lens and 12mm of eye relief. The apparent field of view measures 82°. Orion fully multicoats the optics. The eyepiece weighs 7.4 ounces (210 grams), allowing easy transport.

Price: $197.95
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[w] www.oriontelescopes.com

Zoom eyepiece

Orion Telescopes and Binoculars
Watsonville, California

Orion's Premium Zoom Eyepiece features a focal range of 22.5mm to 7.5mm. It provides a 66° apparent field of view (AFOV) at 22.5mm and a 42° AFOV at 7.5mm. The fully multicoated eyepiece weighs 9 ounces (255g).

Price: $279.95
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Machesney Park, Illinois

Astro-Physics redesigned its 16" Easy-Balance Dovetail Saddle Plate with eight mounting positions to allow easy balancing of front- or rear-heavy imaging setups. You can lock the 1" knobs with an Allen wrench. Accepts all Losmandy "D" plates 12" or longer.

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Astronomical journal

Oberon Design
Santa Rosa, California

Oberon Design's Roof of Heaven leather journal displays a woodcut (from an 1888 book by French astronomer Camille Flammarion) showing a pilgrim gazing into the cosmos. In addition to the sky-blue shown here, four other colors are available.

Prices vary by size: $69.50 (6" x 9", pictured)
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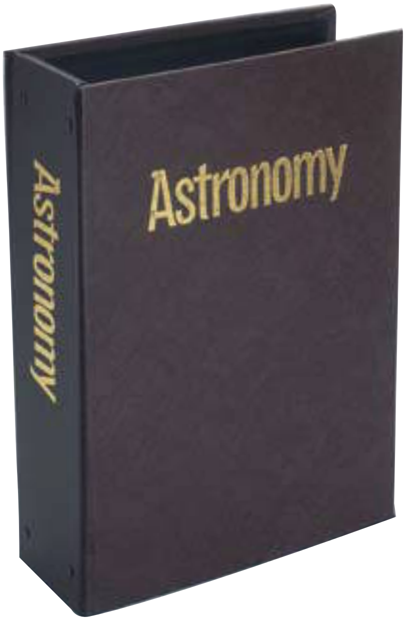

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The Cosmic Grid

All things high, low, weird, and wonderful in astronomy and space science. **by Liz Kruesi**

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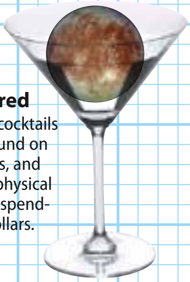
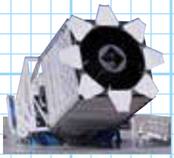


Shaken, stirred
Scientists make ice cocktails similar to those found on Europa, Enceladus, and Titan to study the physical processes without spending billions of dollars.

Family fun at Saturn
The new Floating Planet from Hammacher Schlemmer proves what we learned as children: Saturn's density would allow it to float in a bathtub. Or in a lake.

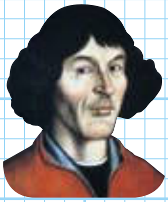


And the winner is ...
Astronomer Juan Madrid's occasional survey of published research concludes that the Sloan Digital Sky Survey's 2.5-meter telescope in New Mexico is the most influential observatory in the world. NASA's Swift satellite takes second place; the Hubble Space Telescope comes in third.

Utah=Mars
It seems Utah makes a good stand-in for the Red Planet. Starting in early 2010, Pixar will begin filming *John Carter of Mars* in the state.

Weightless wedding
A New York couple becomes the first to tie the knot floating in mid-air. How's that for a day to remember?

News briefs
After wearing a pair of underwear for a month on the ISS, Japanese astronaut Koichi Wakata says no one complained of any smell. The test undies are made from specially designed antibacterial and deodorizing materials.



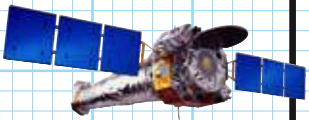
Those baby blues?
Modern astronomy's founding father Nicolas Copernicus likely had blue eyes, according to genetic testing. But they're brown in this portrait. Way to get the science wrong again, big media.

OUT
OF
SERVICE

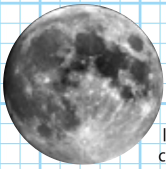
Bathroom break
Astronauts aboard the ISS have a brief scare in July: A toilet aboard the ISS floods as the orbiting ship hosts its largest crowd ever. Space station crewmembers repair the commode, and it's up and running the following day.

Modernizing
Researchers from Harvard work to digitize 525,000 glass photographic plates. That's a century's worth of largely unexamined data. Good luck!

Science (non)fiction
Comic Con isn't just a bunch of nerds running around in costumes. The 2009 event includes a panel about the science of science fiction that discusses *Fringe*, *Eureka*, and, my favorite, *Battlestar Galactica*. Note to self: attend next year.

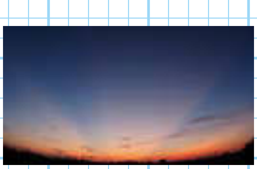


Raise a glass
The Chandra X-ray Observatory celebrates 10 years of studying some of the highest-energy objects in the cosmos. And it's not blind yet.



No telescope needed
Google Inc. creates Google Moon so you can explore lunar details from the comfort of your couch.

That's a rap
Buzz Aldrin teams up with rapper Snoop Dogg to record a single called "Rocket Experience." Seriously.



It's not the camera
Northern Hemisphere observers see lavender sunsets after Russia's Sarychev volcano spews fine aerosols into the stratosphere.

From stargazer to Skywalker
Who says telescopes are only for observing the night sky? Uncle Milton creates a telescope that shows backlit images of the planets and ships featured in *Star Wars*. And Yoda explains them to you!

Say what?
Some 25 percent of Americans from 18 to 25 years of age aren't convinced the Apollo Moon landings happened.

Later, laser
Apollo-era astronauts left four laser reflectors on the Moon. After 40 years of experiments, the National Science Foundation pulls the funding for the lunar laser research.

Snow falling on ... Mars?
The Phoenix Mars Lander spots nightly snow falling from the martian sky during winter. It doesn't hang around the surface long, though. Each day the snow sublimates into gas.

PREDICTABLE

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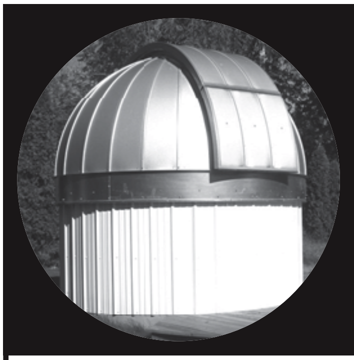

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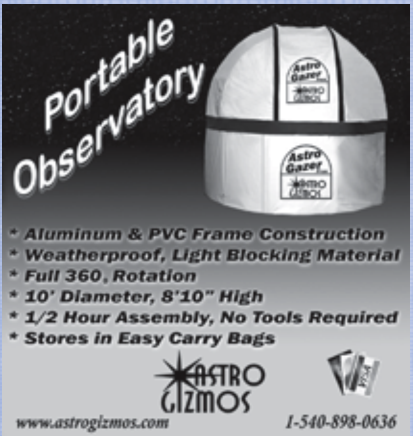

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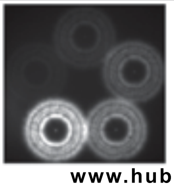

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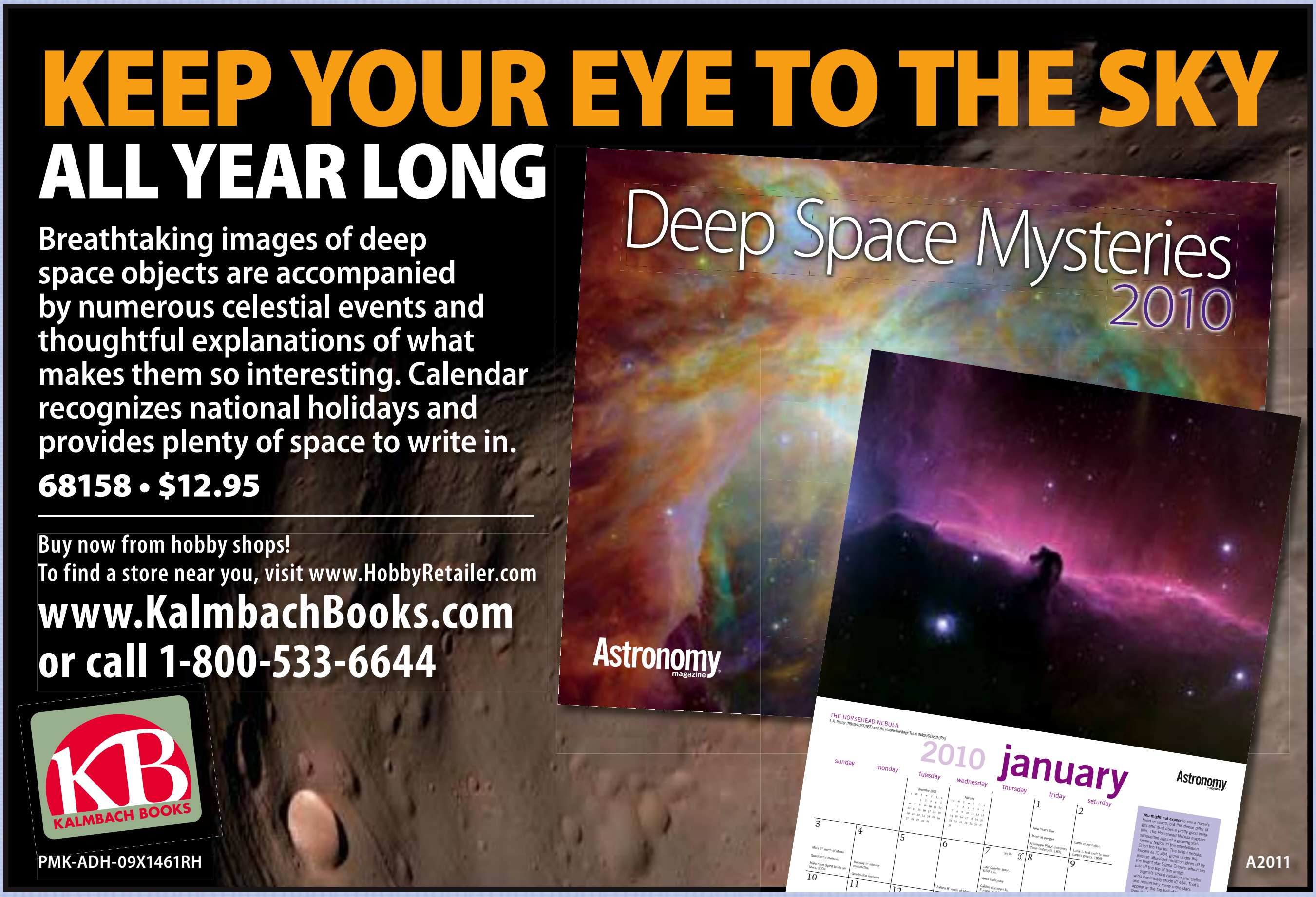
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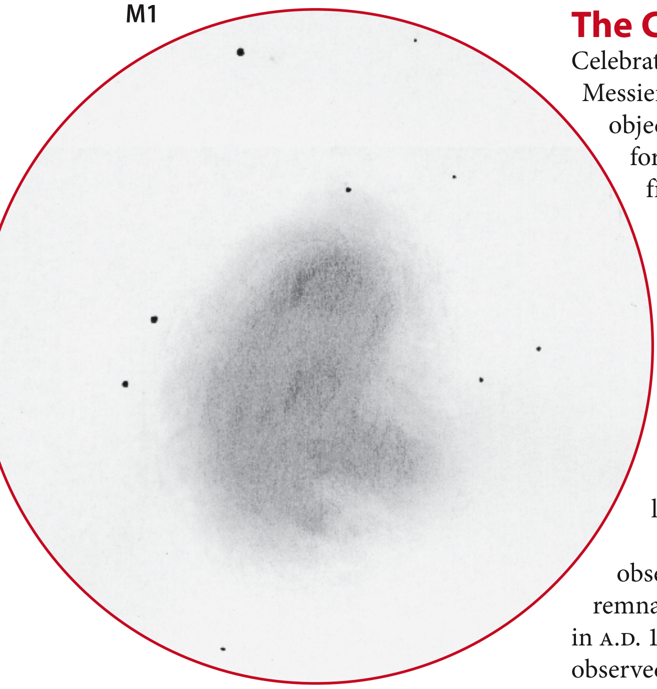
Deep-sky Showcase

The Crab Nebula and NGC 1023

Astronomy's editor sketches two of his favorite objects.

by David J. Eicher

M1



The Crab Nebula sketched by David J. Eicher using a 17.5-inch f/4.5 reflector at 71x.

The Crab Nebula (M1)

Celebrated as the first object in Charles Messier's famous list of deep-sky objects, the Crab Nebula is a favorite for observers. Yet it's relatively difficult to observe because its surface brightness is low. A bright overall magnitude of 8.4 smears over more than 7' of sky, so the Crab appears dim through small scopes. Train an 8-inch or larger scope on the Crab under a dark sky, however, and you'll see an impressive, odd shape that glistens with the eerie light of a gray-green ghost.

The Crab is one of the few easily observable examples of a supernova remnant. The progenitor star erupted in A.D. 1054, and Chinese astronomers observed it as a bright beacon in the sky and chronicled its activity in written records. Only in 1731 did the British observer John Bevis telescopically discover the remnant we now treasure. The pulsar in the midst of the Crab, glowing feebly at magnitude 16, is a powerful emitter of X-rays.

M1

Brian Lula

Designations: M1, NGC 1952
Position: 5h35m, 22°01' (2000.0)
Constellation: Taurus
Magnitude: 8.4
Size: 7.0' by 4.8'
Distance: 6,500 light-years

NGC 1023

Ken Crawford

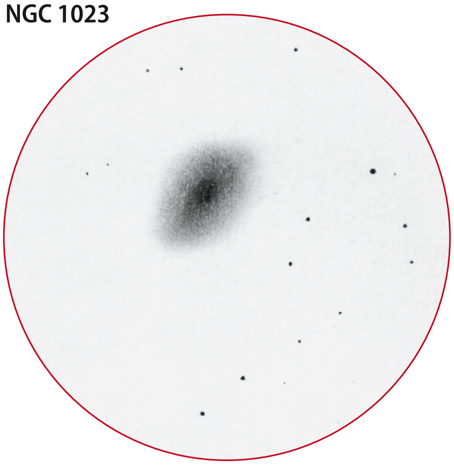
Designations: NGC 1023, Arp 135
Position: 2h40m, 39°04' (2000.0)
Type: SB0 D–
Constellation: Perseus
Magnitude: 9.5
Size: 7.9' by 3.5'
Distance: 34 million light-years

Galaxy NGC 1023

Who looks for galaxies in Perseus, behind the thick winter Milky Way? I do! One of my favorite galaxies in the wintertime sky is NGC 1023, an object that for years was thought to be a lenticular (lens-shaped) peculiar object. Astronomers now classify it as an odd barred spiral seen highly inclined to our line of sight — and with a lens-shaped, bright center. This object is the kingpin in a little group of galaxies that includes other objects familiar to seasoned deep-sky observers — NGC 891, NGC 925, NGC 1058, and NGC 1239.

NGC 1023's surface brightness is relatively high, so it's visible through a small scope on a dark night. An 8-inch scope at low power shows the galaxy's bright core and an envelope of nebulosity surrounding it. The setting in a field of bright stars in the Milky Way makes it particularly appealing. Try cranking up the power to see a brilliant "ball" of light in the galaxy's center, and this object will become a favorite of yours as it is for me.

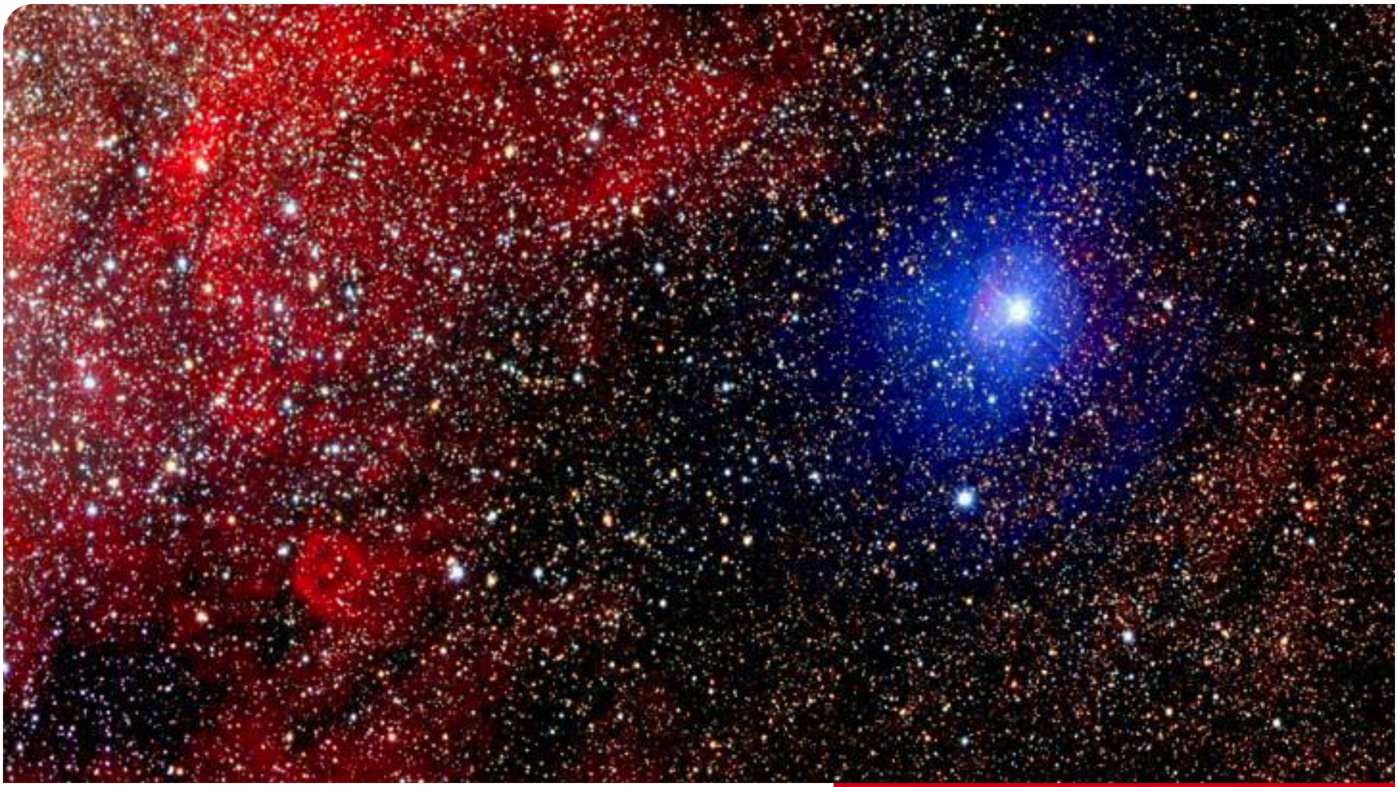
NGC 1023



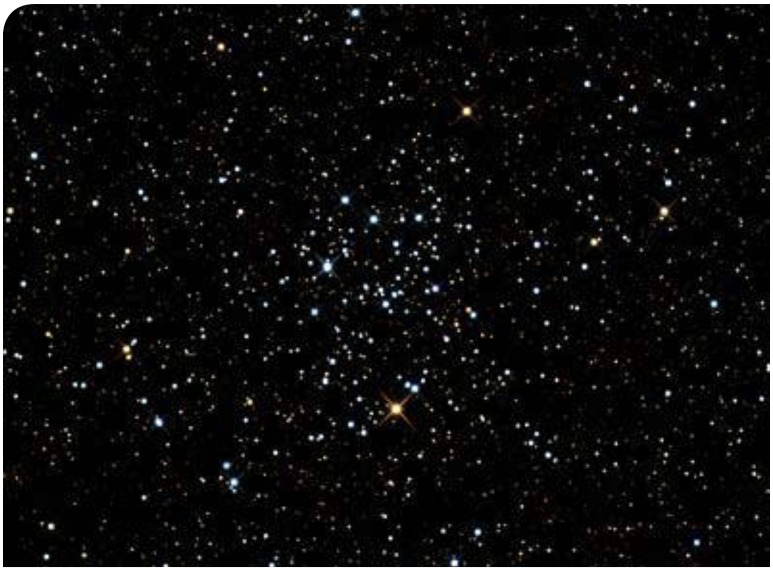
NGC 1023 sketched by David J. Eicher using an 8-inch f/10 SCT at 70x.

David J. Eicher *is the editor of* Astronomy. *He has observed and sketched deep-sky objects for 33 years.*

reader gallery



IC 1287 (7.2-inch Takahashi Epsilon-180 hyperbolic astrograph at f/2.8, SBIG ST-10XME CCD camera, HαGB image with exposures of 140, 40, and 40 minutes, respectively) • Daniel B. Phillips, Oceanside, California

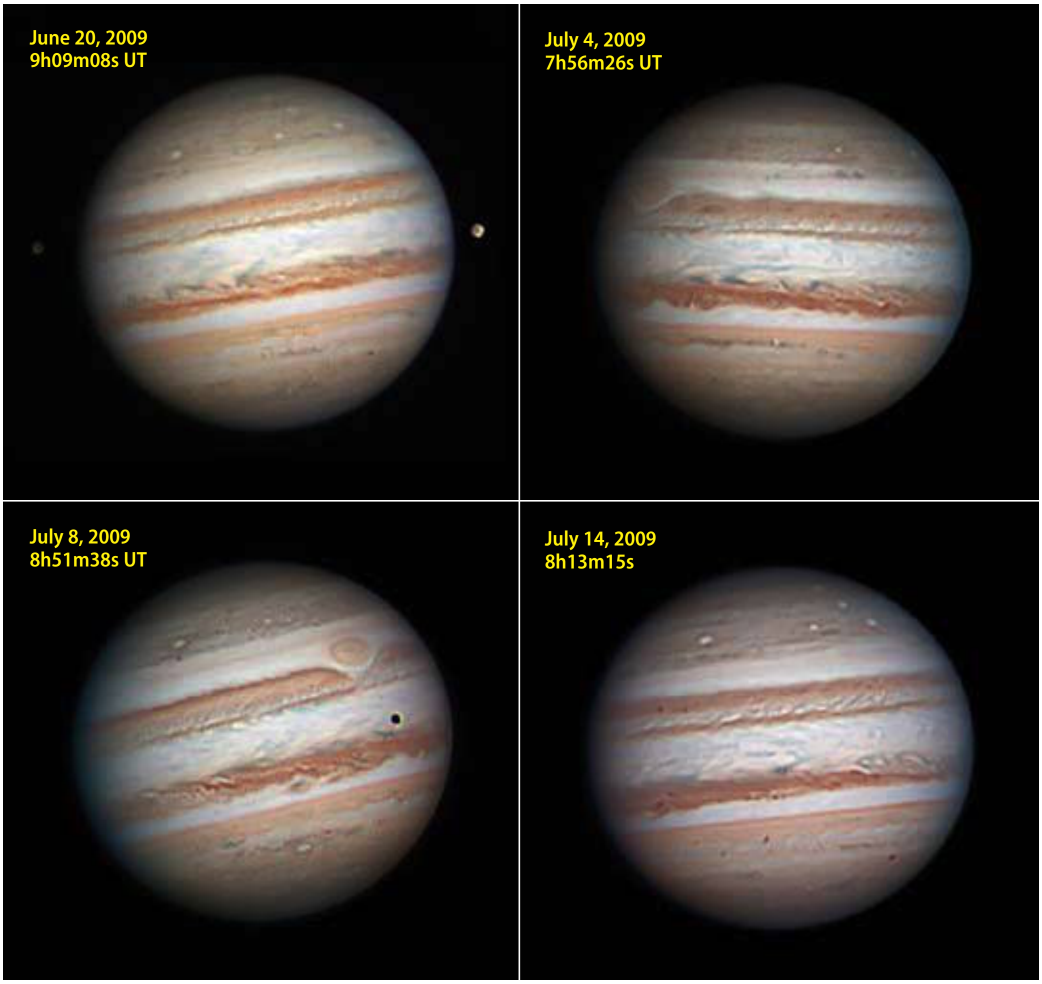


Open cluster M50 in the constellation Monoceros contains some 200 stars and spans 20 light-years. The magnitude 7.8 red giant star SAO 134103 lies just below the cluster's center. (6.4-inch Astro-Physics AP160 StarFire EDF apochromatic refractor at f/7.5, SBIG ST-2000M CCD camera, LRGB image with 30-minute exposures through each filter) • Anthony Ayiomamitis, Athens, Greece

A hidden celestial treasure

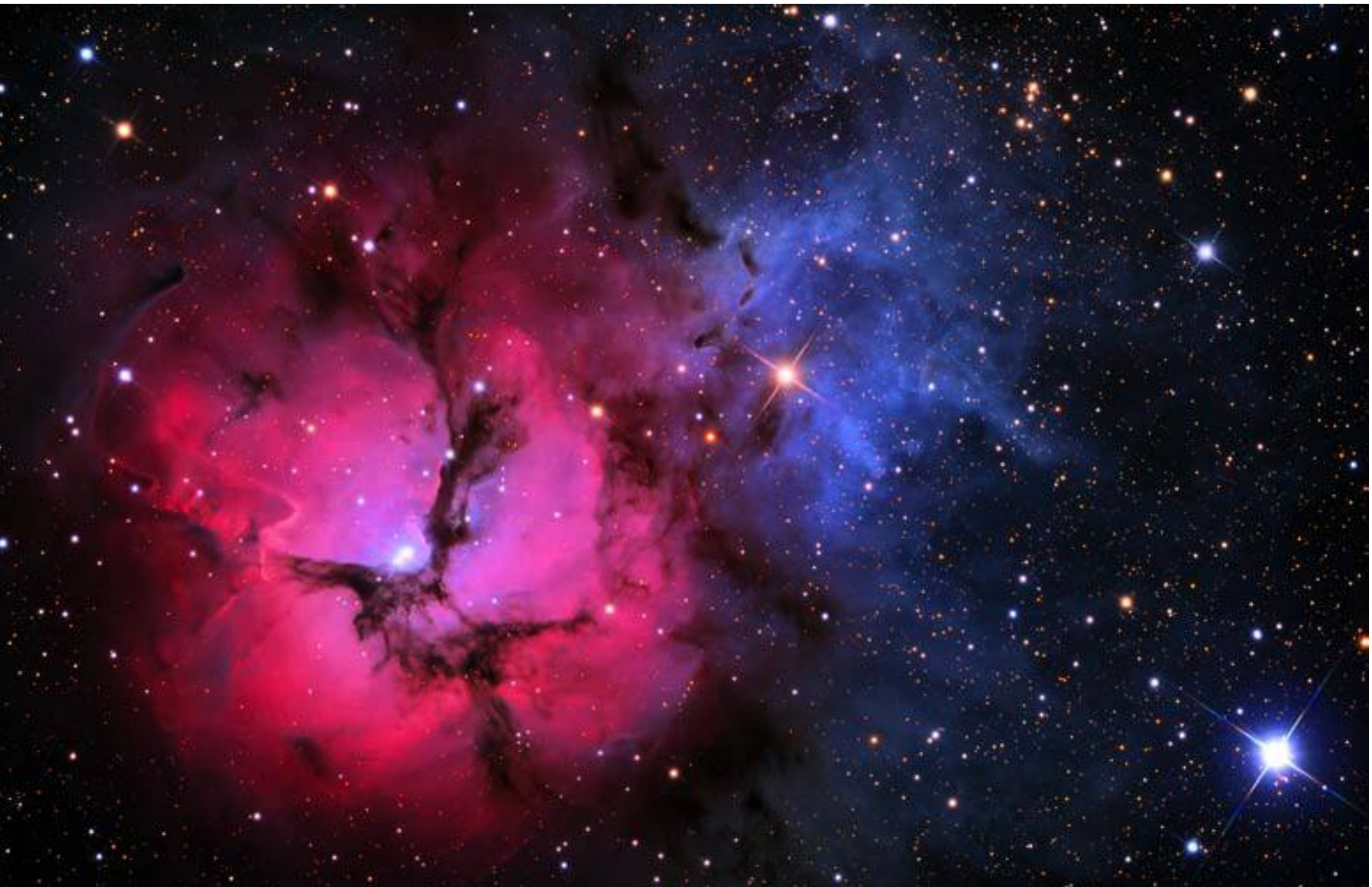
Reflection nebula IC 1287 in Scutum comes with a bonus — planetary nebula Abell 45 (PK 20–0.1). The nebula's blue color arises as it scatters light from the magnitude 5.7 star SAO 161569, which it surrounds. Because of the combination of the star's glare and the nebula's faintness, visual observations of IC 1287 are rare. In contrast, observers who have seen Abell 45 rate it as only "moderately difficult." You'll need at least a 16-inch telescope and superb sky conditions. Even through such an instrument, expect just a round, ever-so-slight brightening of the field of view. A nebula filter (like an Oxygen-III) helps a lot.

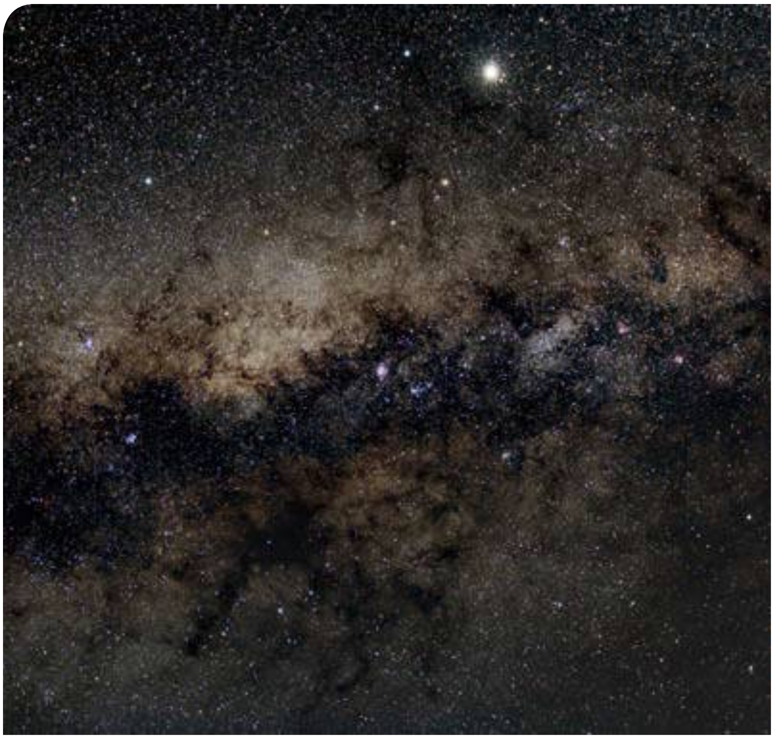
reader gallery


June 20, 2009
9h09m08s UT
July 4, 2009
7h56m26s UT
July 8, 2009
8h51m38s UT
July 14, 2009
8h13m15s

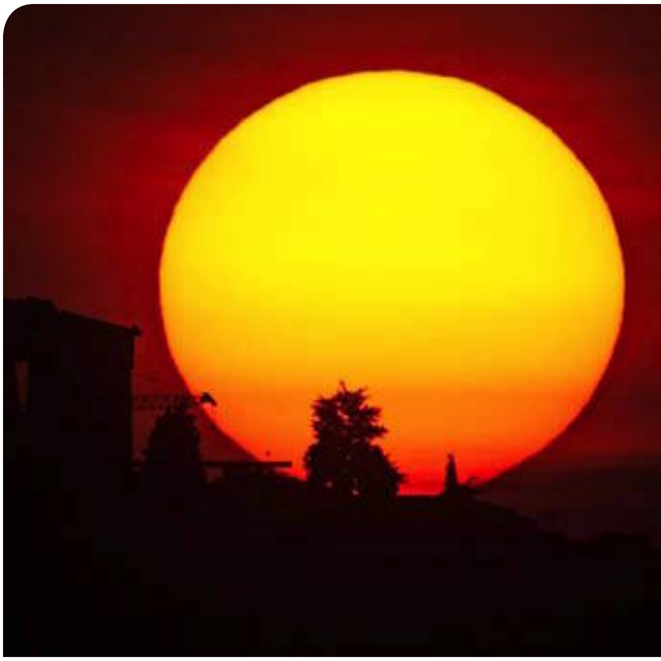
> **Jupiter and its moons** appear different each night. Note the shadow of Europa on Jupiter's cloud tops in the July 8 image. (16-inch homemade Newtonian reflector at f/22, Lumenera SKYnyx 2-0 CCD camera, RGB images using Astrodon filters) • Donald Parker, Coral Gables, Florida

V **The Trifid Nebula** (M20) in Sagittarius is a favorite object among imagers because it combines red emission nebulosity with blue reflection nebulae and dark dust clouds. (24-inch RC Optical Systems Ritchey-Chrétien telescope at f/8, SBIG STL-11000 CCD camera, RGB image with exposures of 80, 50, and 55 minutes, respectively) • Adam Block/Mount Lemmon SkyCenter/University of Arizona

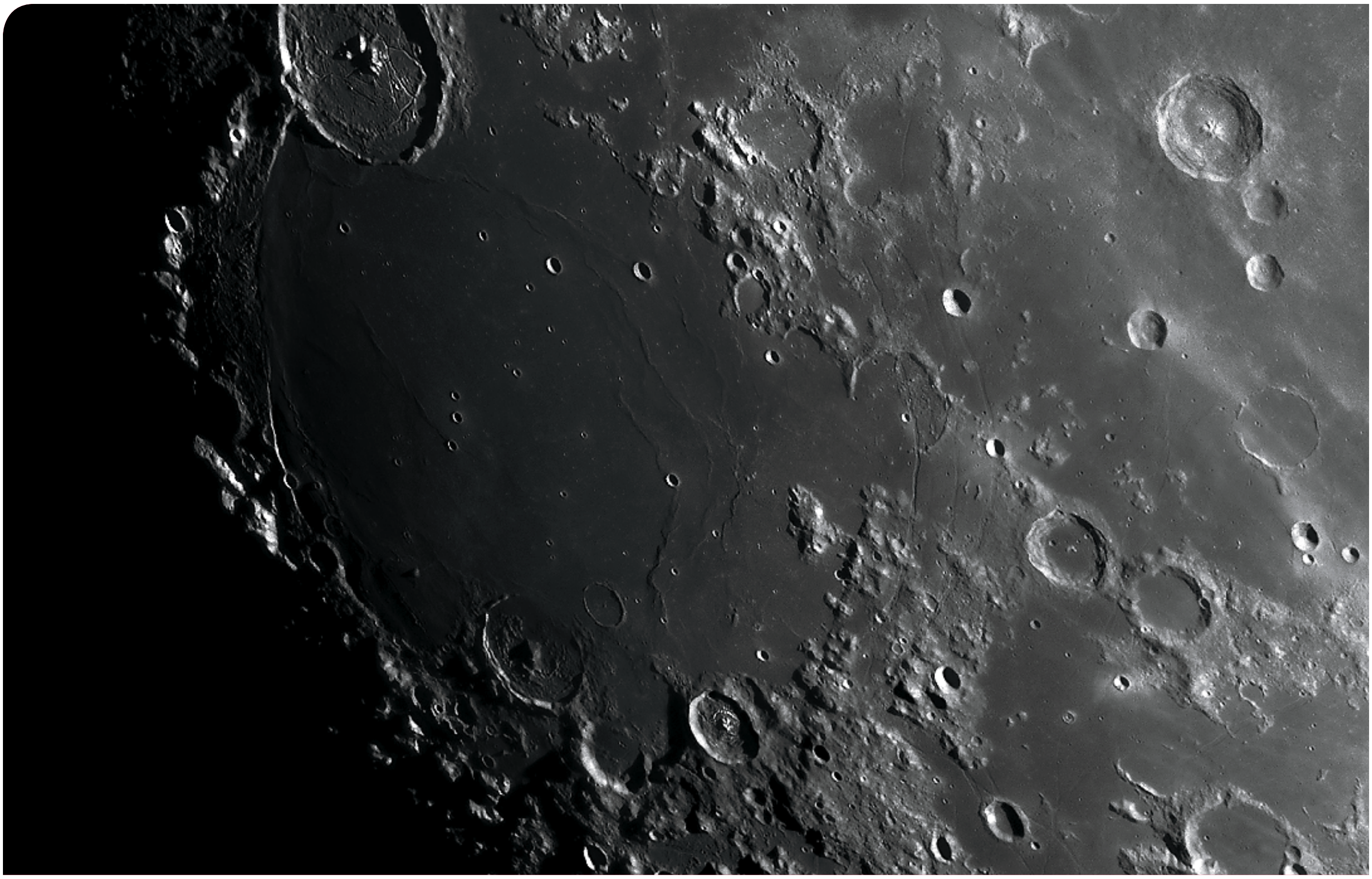




Jupiter hangs in front of the southern Milky Way in this image. During the exposure, Jupiter glimmered to the upper left of the constellation Sagittarius. (Canon 350D digital SLR, Sigma 17-70mm lens, taken September 20, 2008, at Mangrove Mountain in New South Wales) • Mike Salway, Wyoming, Australia



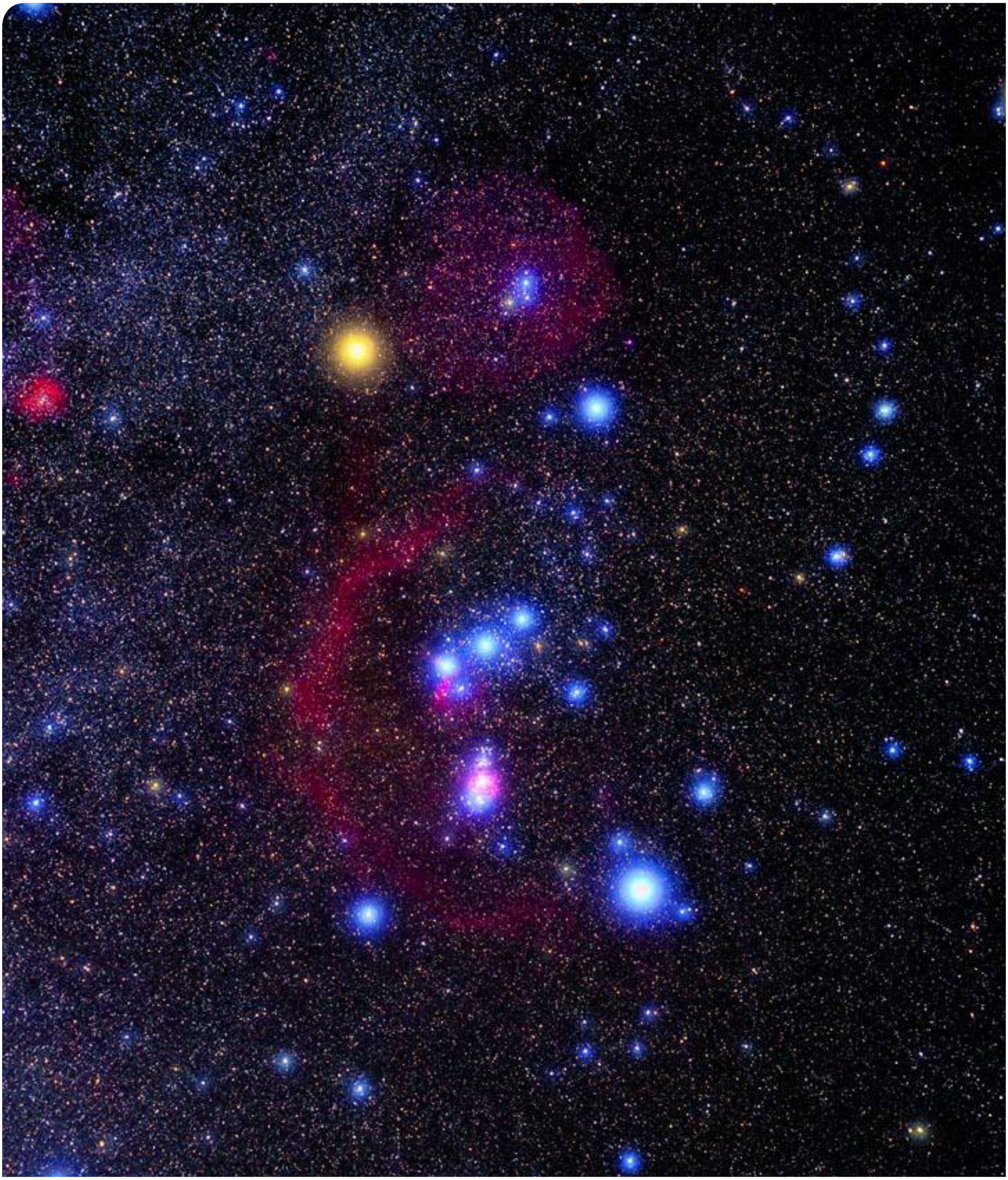
The Sun rises behind the Parthenon on a hazy Athenian morning. To get the right perspective, the imager tried nine different locations. He finally set up 3 miles (4.87 kilometers) southwest of the Acropolis on a highway. (4-inch Takahashi FSQ-106 refractor at f/5, Canon EOS 350D digital SLR, ISO 100, 1⁄1600-second exposure, taken May 6, 2009, at 6:37:02 A.M. local time) • Anthony Ayiomamitis, Athens, Greece



Mare Humorum is a fractured part of the Moon's surface. To enhance detail, the imager shot the area while the Sun stood at a low angle above this part of the lunar landacape. (12.5-inch Lazzarotti Optics Gladius CF-315 telescope, LVI-1392 PRO experimental video camera, best 40 frames out of 2,000, taken between 21h06m UT and 21h17m UT, February 17, 2008) • Paolo Lazzarotti, Massa, Italy

reader gallery

Send your images to: *Astronomy* Reader Gallery, P. O. Box 1612, Waukesha, WI 53187. Please include the date and location of the image and complete photo data: telescope, camera, and exposure information. Submit images by e-mail to readergallery@Astronomy.com.



The constellation Orion is unmistakable on winter nights in the Northern Hemisphere, but only an image shows such detail. Star colors are prominent. Coppery Betelgeuse (Alpha [α] Orionis) in the Hunter's right shoulder contrasts with sapphire-blue Rigel (Beta [β] Orionis), which marks his left foot. (Guided exposure with a special filter that slightly diffuses the bright star images) • **Bill and Sally Fletcher, Little River, California**

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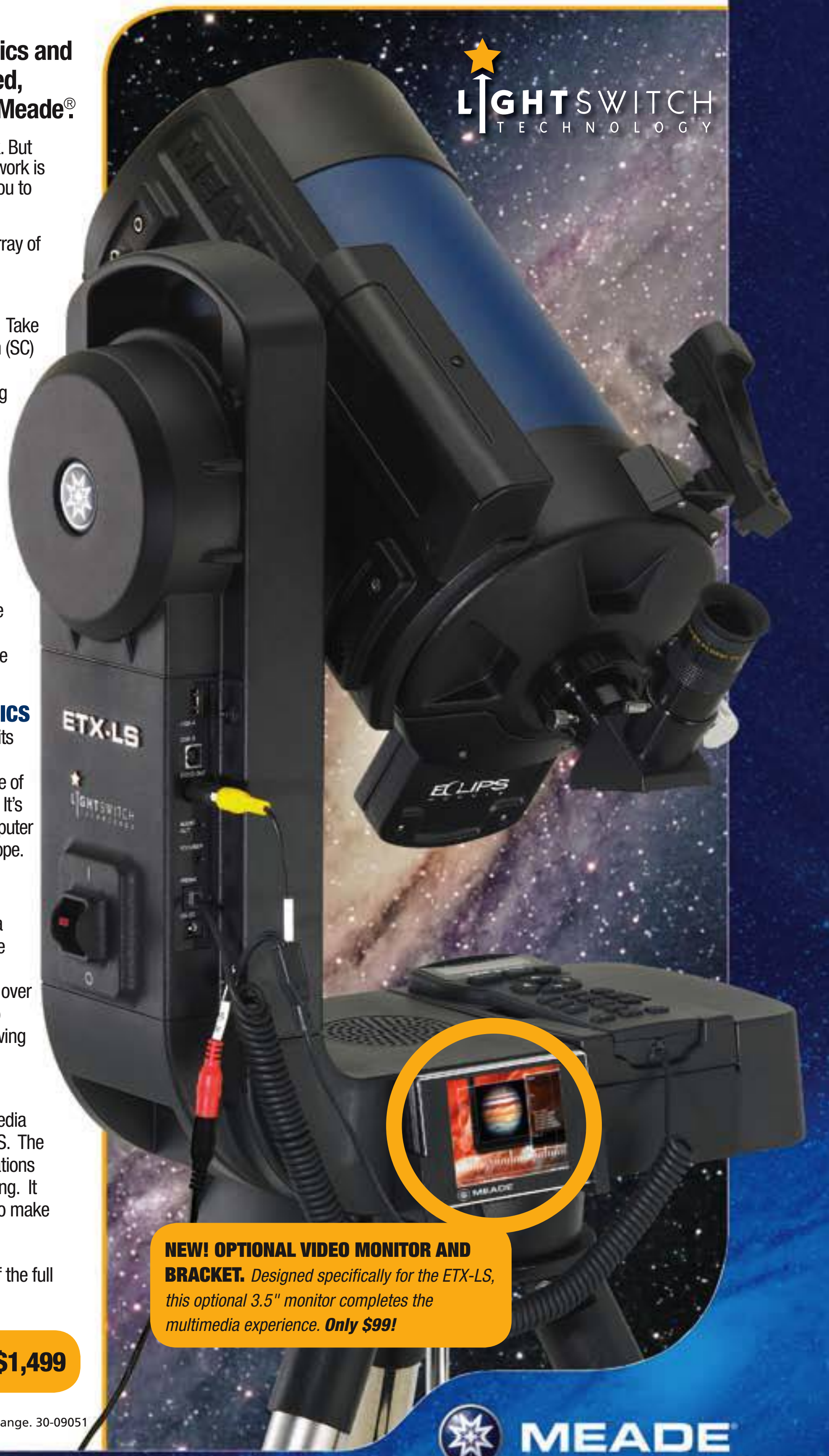

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